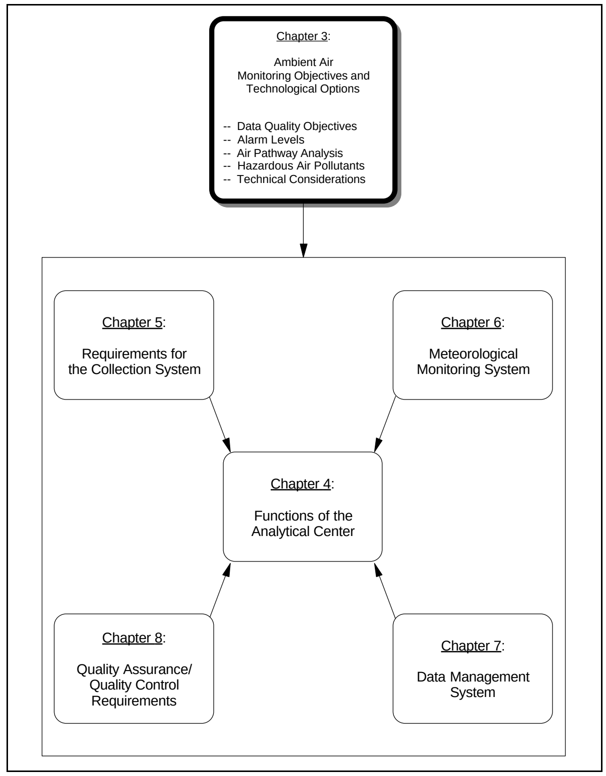
SUMMARY REQUIREMENTS FOR MONITORING OBJECTIVES AND TECHNOLOGICAL OPTIONS

Defining monitoring objectives is the first important step in the design and operation of a FFMS at a HTRW site. The purpose of Chapter 3 of EM 200-1-5 is to discuss the objectives and DQOs of a FFMS with respect to quantifying emissions during different phases of the remediation program. By clearly defining the objectives and DQOs, the Corps is able to successfully assess and characterize effects of pollutant transport via the applicable exposure pathway from the HTRW site.



SECTION I: INTRODUCTION

SECTION II: DATA QUALITY OBJECTIVES (DQOs)
- Introduction
- DQO Process

SECTION III: REGULATORY LIMITS, ACTION LEVELS AND SITE SPECIFIC ALERT LEVELS
- Introduction
- Regulatory Limits
- Action Levels (I-IV)

SECTION IV: EPA's AIR PATHWAY ANALYSIS
- Superfund Process
- Air Pathway Analysis

SECTION V: CHEMICAL AND PHYSICAL PROPERTIES OF HAPs
- Air Emission Mechanism
- Defining HAPs
- Technology for Monitoring HAPs
- Site Specific Target Compound List (TCL)

SECTION VI: TECHNICAL CONSIDERATION IN DEVELOPING A FFMS
- Acceptable Risk-Specific Concentrations
- Monitoring Strategy
- Site Characteristics
- Cost Factor
- Quality Assurance

Chapter 3 discusses the tasks that are crucial to the planning process, including determining data quality objectives, identifying regulatory limits and action levels, investigating properties of HAPs at the

Panel 3-1. Overview of Monitoring Objectives and Technological Options

site, and assessing technical considerations and constraints in designing the FFMS program at the HTRW site.

Panel 3-1. Overview of Monitoring Objectives and Technological Options

3-1. Introduction

The purpose of this Chapter is to discuss the objectives, nature, and mechanisms for quantifying emissions from HTRW sites during different phases of investigation or remediation utilizing a real-time FFMS for applicable volatile organic compounds (VOCs) or particulate-related contaminants. For the assessment and clean-up of HTRW sites, it is necessary to characterize and quantify potential and actual effects of pollutant transport from the site. Clean-up of HTRW sites is performed to assure general environmental protection and the health and safety of the population in close proximity of the site. Contamination at a given site may pose a current or future risk by exposure from a number of potential pathways, which include direct contact with the in-situ pollutants, subsurface migration of the contaminants via vapor plumes or ground-water plumes, contamination of surface waters, and atmospheric transport (and deposition) of gaseous, aerosols, or wind-blown contaminants. To successfully assess and clean up a HTRW site, it is necessary to characterize the potential effects of pollutant transport via the applicable exposure pathways for each step of the assessment and clean-up process. Verification of these exposures must be included in the establishing of the project DQOs.

3-2. Data Quality Objectives (DQOs)

a. Introduction. DQOs are qualitative and quantitative statements derived from the DQO process that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. The DQO process is an important planning tool to determine the type, quantity, and quality of data needed to support decisions. The DQO process helps develop statements of the level of uncertainty a decision maker is willing to accept when making decisions based on the air monitoring data. DQOs differ from data quality indicators, (such as measurement precision and accuracy), in that they express the limits of the overall uncertainty of a project's results in terms of the probability and consequences of making a wrong decision (rather than as the limits of uncertainty about specific measurements). DQOs play an important role in setting the stage for data quality assessment (DQA).

When environmental data are used to support a decision, for example, the decision maker needs to ensure that the data will support the decision with satisfactory confidence. If the data exhibit a large amount of variability, then the decision maker may be faced with some difficult questions. Do the data indicate that the environmental characteristics of interest are exhibiting a large amount of natural or inherent variability? If so, how does this variability complicate the task of making a sound decision? On the other hand, does the variability in the data indicate that there are problems with the measurement system used to generate the data? If so, what can be learned from this data, and what can be done to improve the quality of data collected in the future? These kinds of questions can be answered by the DQA process. The DQA process is a statistical and scientific evaluation of the data set to assess the validity and performance of the data collection design and statistical test, and to establish whether a data set is adequate for its intended use.

b. DQO process. The DQO process begins with the statement of a potential or real ambient air problem at a HTRW site and defines one or more decisions that will be made to resolve the problem. The subsequent

DQO steps define why and how the ambient air monitoring measurements are being performed and concludes with optimizing the FFMS which will provide the required data and acceptable data quality. EPA defines the DQO process as: "A scientific planning tool to facilitate the efficient and effective planning of environmental data collection activities." For application to FFMS and off-site monitoring the environmental data includes the project defined contaminants of concern that are migrating both on-site as background concentrations and at the fence-line or off-site as fugitive emissions. EPA also defines DQOs themselves as "Qualitative or quantitative statements developed by the data user to specify the quality of data needed to support decisions." For this application the data will be used to support such action decisions as the implementation of engineering controls, a cessation of site activities, initiation of contingency sampling, public required information, system performance monitoring, etc.

Implementation of the DQO process effects three benefits, which include: (1) optimization of sampling and analysis design. (2) maximization of resource efficiency and; (3) improved decision making. The use of real time monitoring in the SAP design can optimize the real time contaminant concentration measurement and identify the need for more accurate real-time contaminant quantification. The sampling and analysis design should include the threshold or action level concentrations at which an action such as contingency sampling and/or site activity corrective actions must be implemented.

Figure 3-1(a) presents the seven major elements of EPA's DQO process, while Figure 3-1(b) presents this process as applicable to HTRW ambient air monitoring program requirements.

(1) Step 1: State the problem. This first step of the DQO process involves the identification and involvement of the DQO team members and stating the problem that results from the HTRW project site and site activities. The DQO process team should involve project directors, engineers, chemists, geologists, risk assessors, air monitoring personnel, regulators, etc. For all ambient air monitoring decisions which are driven by regulatory requirements, the Federal, state or local project related regulatory personnel should be included in the DQO process team. For HTRW projects, the problem can be generically stated as "Activities at the site will generate air emission problems which must be dealt with by one or more decisions." These decisions can be made with a sufficient amount of ambient air monitoring data of a specified quality. Such decisions may be required for sites at which contaminants of concern are present and at which site activities will occur that have the potential for a release or for the transfer of airborne contaminants off-site. The activities may involve site investigation, material removal or contaminated material remediation.

The need for perimeter and off-site ambient air monitoring may also be dictated by the results of an APA, a state or local regulatory air monitoring requirement or as a result of negotiations with local citizens who may be impacted by the off-site contaminant migration. It should be kept in mind that some air monitoring may involve background air monitoring in the absence of any activities at the site as support data for some anticipated future activity. The project/site description statements must include terrain, climate, remoteness, meteorology (both known and unknown), surroundings, etc. The DQO process will also require identification of the type of site activities that will be conducted or that can be anticipated to occur. This first step should result in information upon which the rest of the DQO process will be conducted. As a working example, a site contaminated with benzene, ethyl benzene, toluene and xylene (BETX) is to be excavated.

1. State the Problem

Summarize the contamination problem that will require new environmental data, and identify the resources available to resolve the problem.

2. Identify the Decision

Identify the decision that requires new environmental data to address the contamination problem.

3. Identify Inputs to the Decision

Identify the information needed to support the decision, and specify which inputs require new environmental measurements.

4. Define the Study Boundaries

Specify the spatial and temporal aspects of the environmental media that the data must represent to support the decision.

5. Develop a Decision Rule

Develop a logical "if...then" statement that defines the conditions that would cause the decision maker to choose among alternative actions.

6. Specify Limits on Decision Errors

Specify the decision makers acceptable limits on decision errors, which are used to establish performance goals for limiting uncertainty in the data.

7. Optimize the Design for Obtaining Data

Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs.

Figure 3-1(a). Seven steps associated with EPA's DQO process.

1. State the Problem

Identify the site, state the off-site migration potential, the contaminants of concern and the requirements for fenceline and/or off-site ambient air monitoring.

2. Identify the Decision

Identify the decision(s) that requires ambient air monitoring including the potential and real resulting actions which may be required as a result of the decisions.

3. Identify Inputs to the Decision

Identify the information needed to support the decision(s) and specify which type of ambient air monitoring inputs will be required for each decision(s).

4. Define the Study Boundaries

Specify the spatial and temporal sspects of the project included in the ambient air monitoring requirements including upwind, downwind, sensitive receptors, meteorology, etc., applicable to the decision.

5. Develop a Decision Rule

Develop a logical "if...then" statement(s) that defines the conditions or aspects that would cause the decision maker to choose among alternative actions or contingencies.

6. Specify Limits on Decision Errors

Specify the decision makers acceptable limits or criteria on decision errors, which are used to establish performance goals for limiting uncertainty in the ambient air monitoring data.

7. Optimize the Design for Obtaining Data

Identify the most resource-effective ambient air monitoring design for generating data that are expected to satisfy the DQOs.

Figure 3-1(b). Seven steps associated with the DQO process as applied to air monitoring at HTRW sites.

The site is located in a remote area with two private households within an area that could possibly be affected by a plume originating from the site. The local regulatory agency has indicated that any site generated VOC emissions must be measured by monitoring at the fenceline. To implement Step 1, the problem simply stated, is "*Emissions, which may adversely affect the health and safety of the nearby environments and residents, may be generated from a site contaminated with BETX during the site excavation activities, and consequently BTEX or an indicating parameter must be monitored.*"

(2) Step 2: Identify the decision. The second step in the DQO process involves the identification of the decision which will solve the potential or real ambient air problem. This step also establishes the alternative steps that may be implemented based on the outcome of the ambient air measurements. This step should be used to generate subdecisions which support the principle decisions. These subdecisions are a part of the

iterative nature of the DQO process and are often generated as part of Step 7, which are steps to optimize the air monitoring system design without compromising the initial decision. It should be noted that for each subdecision, Step 5 should generate additional "if...then" statements which are compatible with the previous statements and which default to the higher level decision. A subdecision may involve the monitoring of NonMethane Organic compounds (NMOCs) as an indicator of the presence of BETX.

Continuing with the example, monitoring for the off-site migration of BETX will assure the health and safety of the two receptors of concern, the two private household occupants. Should the off-site migration of BETX components be detected during the excavation activities when either of the receptors of concern are within the meteorological plume, a corrective action must be implemented. The results of Step 2, can be stated in the example as *"The detection of any BETX component migration off-site during excavation that impacts either receptor of concern will require corrective action"*. The appropriate corrective action will be defined later in the DQO process.

(3) Step 3: Identify Inputs to the Decision. Identification of the decision inputs requires identification of the applicable data users and regulators and the information that they will require to solve the decision statement. Regulators typically provide or should confirm compound and/or parameter action levels based on emission factors, risk-determined action levels, ambient air requirements, etc. Citizen groups often demand concentration data that assures the site activities are not resulting in adverse health affects to area residents. These groups also require that the monitoring data be a direct reflection or a reliable indicator that a site activity is being conducted according to design or in a manner which assures the health and safety of the local residents on a continuing basis. This data can also be used by the personnel with oversight responsibilities for the activities to assure the activities are being performed in the planned or contractually required manner. An important part of the decision process is identifying who the decision makers are and where they are located. Real-time ambient air monitoring data can be transmitted electronically from a remote site location to a contractor's or regulator's office. Such needs will impact the air monitoring system design.

The use of real-time monitors as part of a FFMS offers immediate on-site, perimeter and off-site contaminant concentration data that can be used to make decisions that require immediate implementation of contingency plans. The detection of specific compounds on a real-time basis can determine if engineering control practices must be implemented, site activities must be decreased or halted, action levels have been reached or exceeded that require contingency sampling.

For the BETX excavation example, monitors may only be required which detect BETX migration off-site during excavation which impact on the residences. It may be feasible however to monitor for NMOC with a BETX confirmation measurement as a contingency. Identifying inputs to the decision would therefore require monitoring NMOC/BETX at the fenceline during excavation whenever the receptors of concern are within the site plume. Determination of whether the receptors are within the plume at any given time however, requires that site meteorology be monitored or obtained from an acceptable near-by meteorological monitoring station. The meteorological data must include the atmospheric stability class to determine the receptor impact. The regulators should provide required method detection limits based on existing regulations, risk based dispersion modeling, or measurement based technology. The results of Step 3 for the example site can be stated as: *"Meteorological and NMOC/BETX monitoring must be performed to indicate whether the BETX emissions are having an impact on the receptors of concern during excavation activities."*

(4) Step 4: Define the Study Boundaries. Identification of the boundaries requires defining both the spatial and temporal project boundaries. Identification of the spatial boundaries is often difficult for some projects and is contingent on the decision makers domain. The project boundaries are not confined to the site for air monitoring and often involve off-site air monitoring and tracer release, detection and modeling activities. Air monitoring may involve either or both volatile and semi-volatile compounds or particulate related matter. Boundaries often are variable with changing meteorological conditions. A receptor of concern which is in the site plume during certain meteorological conditions will not necessarily be within the boundaries when the conditions change. For regulatory purposes, the boundaries may be defined by the specific project emissions source types while the boundaries defined by citizen groups may include sensitive receptors. For this reason, the DQO process team established in Step 1 should be involved in defining the spatial and temporal boundaries.

The spatial boundaries of the example BETX contaminated site during excavation activities will be a function of when the site plume can impact on either receptor of concern. Depending on whether the regulator or other data user specifies that the results of a total BETX concentration measurement at the site fenceline requires a corrective action or specifies that the determination of BETX generated exclusively by the on-site excavation requires the action, will dictate whether background measurements are required. The spatial boundaries can therefore, include background air contaminants migrating on-site in addition to those migrating off-site. The temporal boundary for this example may include two boundaries, one for the entire duration of the excavation activities and one for monitoring periods in which the receptors of concern are within the site plume. The results of Step 4 for the example may be stated as; *"Monitoring will be performed both at the upwind and downwind perimeter of the HTRW site for NMOC/BETX, whenever the receptors are impacted by the BETX emissions, for the duration of the excavation."*

(5) Step 5: Develop a Decision Rule. The development of a decision rule often requires the establishment of one or more "if,...then" statements. Each decision rule should be composed of four elements: The parameter of interest, the scale of the decision, the action level for that decision, and the alternative action. Sometimes the decision rule is composed of a series of prioritized subdecision statements. A subdecision statement for air monitoring could be "*If a threshold limit is exceeded for a specified measurement, then a confirmation measurement must be performed*." This action may then be followed by a second subdecision statement that "*if the threshold limit exceedence is confirmed, then compound speciation must be performed, on-site corrective action taken or site activities terminated*."

The development of the decision and subdecision rules is an important part of the DQO iterative process. While the iterative process should not change the primary decisions, Steps 5, 6, and 7 should generate additional subdecisions and additional "if....then" statements as the measurement program is optimized. Each subdecision should contain the parameter of interest, the action level, the alternative action appropriate to the subdecision, and the scale of the decision when different from the principle decision.

For the BETX example project, implementating Step 5 may result in the statement; "*If the NMOC concentration exceeds the action level and a BETX measurement confirms the NMOC results during the time when the receptors are impacted by BETX emissions, <u>then</u> either engineering controls to diminish the BETX emissions are applied or the excavation activities are halted.*"

(6) Step 6: Specify Limits on Decision Errors. The decision errors will likely rely on the specific component measurement requirements and how near the measurements must be to the true values. This step of the DQO process often generates the Project DQOs in terms of precision, accuracy, representativeness, comparability, completeness, method sensitivities (method detection limits) and data validation and reporting requirements.

For the DQO process for ambient air monitoring at HTRW sites, precision and accuracy are often key elements in the iterative subdecision-optimization process steps. The precision of an air contaminant measurement is taken as the variance between two or more measurements. This often results in "if...then" statements which require a repeat of a given measurement. If the result of the repeated measurement is averaged with the initial measurement, the result must be within an acceptable (and defined) variance. The variance between the measurements is expressed as relative standard deviation (RSD). The acceptable RSD of a required measurement should always be defined and stated as one of the project DQOs.

The confidence the decision maker has in the measurement technology or technique relies on the accuracy of the measurement. The accuracy of the measurement can be defined in numerous ways including the measurement result relative to a standard reference method measurement, the result of the measurement when subjected to a well known standard contaminant concentration or the result of a measurement audit procedure. Relative accuracy is usually expressed as the percent deviation from the accepted method result or analysis of a standard. The accuracy of each required measurement should be clearly defined during this step of the DQO process and should include the method of determining accuracy.

An additional characteristic of data quality is representativeness. Representativeness is not expressed quantitatively but relies on project specific and good scientific judgments. A major part of measurement representativeness for HTRW FFMS is the spatial boundaries defined by the fourth DQO process step. Due to the nature of the variability of ambient air, representativeness must address site micrometeorology, monitor siting, diurnal and climatic changes, etc. Comparability is another key DQO element when optimizing the SAP. With the addition of more "if...then" statements which may involve differing contaminant measurement technologies, the resulting data must be comparable to and support the higher decision statement and its requirements.

Completeness as applied to an HTRW project DQO involves a set number of contaminant measurements. The number of measurements may be defined within a decision statement with its measurement requirements or may be applicable to continuous monitoring or the sampling schedule.

Method detection limits are involved in the component of concern threshold or action level monitoring. Regardless of whether the measurement method is instrumental or a manual sample with subsequent laboratory analysis, the minimum detection limit must always be stated. The ambient air measurement detection limit should always be made known to an analytical laboratory and analytical evidence required that the decision limit can be achieved. For instrumental monitoring, the detection limit stated by an instrument manufacturer may not be applicable to the specific project. A calibration or audit gas at or near the required detection limit will provide evidence that detection limits are achieved.

Data validation and reporting can be key components to the decision maker. The probability that a false positive or false negative decision will be made increases as the data validation decreases. The timeliness of the data reporting also can be key to the decision maker. For decision alternatives which require immediate actions, real time air monitoring data will be a requirement.

Decision error limits often involve the verification of a contaminant detection beyond an action level. The DQO process must define the measurement precision and accuracy acceptable to make the decision. One method of assuring that precision and accuracy are defined project DQOs for all measurements is to include them in the "if...then" statements, as in the example case below. The decision maker must also agree that the measurement is representative of the air media for which the action level applies. For real-time air monitors the detection of an action limit exceedence is typically confirmed with a duplicate measurement or by the use of a manual reference measurement method. Such decision rules may involve complex contractual details that must be well defined, such as the implementation of dispersion modeling, the implementation of on-site engineering controls or activity limitations that impact the contractors efficiency.

In order to assure the detection of NMOC and BETX off-site migration at the example site, the decision maker must define the accuracy and precision of the measurements. This may be accomplished by including the required precision and accuracy in the "if...then" statements. Step 6 should provide statements such as; " *If the measurement values for NMOC and BETX meet a precision of* $\pm$*30% and an accuracy of 70 to 130% , and are supported by documented representativeness and comparability during the time the receptors are impacted by BETX emissions, then the specified corrective action must be implemented*

(7) Step 7: Optimize the Design for Obtaining Data. The optimization of the data acquisition design is typically necessitated by project funds and air monitoring cost effectiveness. Cost reductions and air monitoring efficiency can often be achieved without precision and accuracy compromise. Any compromises must always be acceptable to the decision maker. The optimization can also be achieved by fine-tuning sample representativeness, sampling data reporting, acceptable levels of data quantity and data validation limitations. Air sampling is best optimized by avoiding unnecessary data quality, measurement methods, detection limits, QC requirements, etc. Air monitoring can nearly always be optimized considering the absence of receptors when meteorological conditions are considered. When the on-site activities are of extensive length the use of automated monitors provides an optimization not achievable using manual sampling and sample analysis.

Optimization must always be accomplished with the generation of additional "if...then" statements which support the additional subdecisions. The lowest subdecision and the related air monitoring requirements can often involve low cost acquisition and analysis using screening measurements. The rationale that "<u>if the concentration of a class of components is less than a defined action level then the components of concern within that class must be less than the action level"</u> allows for the use of cost effective measurement methods. Such methods may measure an entire class of compounds and provide a result in terms of concentrations less than the action level. The associated "if...then" statement must include the "then" portion, the alternative which reverts to the next higher decision statement. This iterative process of optimization maintains the integrity of the initial decision statement(s) defined in step two of the process. Several of the more common factors to consider in optimizing air monitoring plans for HTRW site activities include the following:

- The systematic monitoring of a chemical compound class (i.e., NMOCs using a photoionization detector (PID)) rather than using a gas chromatograph (GC) to separate the NMOCs for individual compound quantification can significantly reduce monitoring and calibration apparatus requirements and can also reduce manpower requirements for data reduction and reporting.

- The collection and analysis of specific compounds which are representative of a total class of compounds of concern needed by the decision maker can optimize the air monitoring approach. If the decision maker requires the concentration of semi-volatile organics for example, the need may be satisfied by the measurement of the most volatile (i.e., naphthalene) or the measurement of benzo(a)pyrene, which is one of the most carcinogenic compounds of the semi-volatile group, and thus represents the greatest risk. In such an instance, the field sampling and/or laboratory analysis could be greatly simplified.

- The use of historical site related meteorological data can greatly effect the temporal boundaries of the project established in the fourth step of the DQO process . For project specific receptors which drive the decisions, the absence of any receptors in the downwind plume of the site emissions can alleviate the need for air monitoring. A typical dispersion model will address concentrations based on the yearly wind rose. However, if the dispersion modeling is performed on a monthly basis it may be clear that the receptors are not affected during certain time intervals and thus the temporal boundaries can be lessened.

- Not all site activities are performed on a continued basis. Where the activities are limited to certain seasons, daytime hours or weekdays, the air monitoring activities can be optimized accordingly. This can be accomplished by the selection of measurement methods which are not based on 24-hour sampling time intervals, using automated samplers which can be programmed to sample during prescribed time intervals, or using low cost portable measurement devices which can be easily maneuvered into the downwind plume during the activities. The optimization process may involve the acceptance of short-time measurement methods which require a compromise of sensitivity due to shorter sampling intervals.

- The most relevant factor in the optimization step can be the decision error probability for real-time instrumental monitoring versus manual grab sampling and laboratory analysis. Depending on the "if...then" statement that supports the primary decision, it may be necessary to require real time ambient air monitoring. Depending on project specific spatial boundaries, the decision maker may have to implement immediate corrective actions when threshold values are met or exceeded. For such projects real-time ambient air monitoring will be a must and can be accomplished using a fixed fence-line monitoring system, long path fourier transfer infrared spectroscopy (FTIR) monitoring, or other real-time measurement technology.

For the example BETX site, the results of optimizing the design in Step 7, may result in a subdecision statement such as; " *If, during the time when the receptors can be impacted by BETX emissions, NMOC measurements which meet a precision of ±30% and an accuracy of 70 to 130% using a confirmation measurement, exceeds the threshold limit, then BETX speciation and quantification measurements must be performed." The higher decision statement then reads; "If the BETX measurements which meet a precision* *of ±30% and an accuracy of 70 to 130% , using a confirmation measurement exceed the threshold limit, then the corrective action must be implemented."* This succession of decision and subdecision allows for both the optimization of acquiring air monitoring data while maintaining the decision maker's acceptable decision error limits.

c. DQOs and incorrect decisions. DQOs are expressed in terms of acceptable probabilities that the measurement results will not lead to incorrect decisions. Two general types of incorrect decisions can occur: false positive errors and false negative errors. False positive errors result in decisions to take action to reduce pollutant exposures when the true concentrations are actually below levels of concern. False negative errors result in not taking action when, in fact, concentration levels are above those thought to pose a serious risk. While false negative errors are usually more detrimental because of the health risks that might unknowingly be imposed on the public, false positive errors are also counterproductive because of the money and time wasted taking unnecessary action. DQOs, therefore, place limits on the acceptable probabilities that either a false positive or false negative error will be made. The acceptable probability that a measurement result will lead to an incorrect decision should depend on the seriousness of the consequences of the incorrect decision. The following examples of APA data quality objectives demonstrate the relationship between acceptable probability rates and the seriousness of the incorrect decision

- At a true concentration of ½ the level of concern, the probability of a **false positive** finding should be less than 10% (i.e., at least 90% of the time, the data would correctly indicate that there is no problem).

- When the true concentration is 1½ times the level of concern, the probability of a **false negative** finding should be less than 5% (i.e., at least 95% of the time, the monitoring data would correctly indicate that there is a problem).

The probability of a false finding is directly and quantitatively related to the accuracy and precision of the measurement method. For instance, in the examples above, a measurement method with a precision of 20% (expressed as relative standard deviation) and no systematic biases would be needed to satisfy each of the these conditions.

In addition to quantitative limits of data quality, DQOs must also be defined qualitatively in terms of representativeness and comparability. Representativeness refers to the specific conditions of space and time to which measurement value is intended to relate. For example, if data are to be compared within 30-minute inhalation-based action levels, the measurement values must be representative of conditions in the typical breathing zone (i.e., approximately 5' to 6' above ground in an area with unrestricted air flow) and averaged over 30-minute intervals. Comparability refers to assurances that the measurement results are expressed in a manner and format that enables direct comparison with applicable action levels (i.e., standardized units) or, if necessary, with other, similar types of data.

3-3. Regulatory Limits, Action Levels, and Site Specific Alert Levels and Triggering Mechanism

a. Introduction. One important purpose for conducting a real-time, fixed-site perimeter monitoring program is to demonstrate compliance with Federal, State, and local regulatory limits during site investigation and remediation activities. Additionally, monitoring data are used to determine whether *action levels* intended to protect worker and public health have been exceeded. Thus, an understanding of the regulatory framework surrounding site activities and the potential for exposure to harmful air contaminants is essential for designing and conducting the monitoring program.

The relevance of regulatory limits and action levels to the design of the USACE fenceline monitoring programs is described below.

b. Regulatory limits. Many fenceline monitoring programs involve Superfund site remediation. Under CERCLA and Superfund Amendments and Reauthorization Act (SARA), on-site remedial actions must attain (or have waived) Federal and more stringent State applicable or relevant and appropriate requirements (ARARs) for environmental protection. Additionally, the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) requires compliance with ARARs during remedial actions as well as at completion and compels attainment of ARARs during removal actions to the extent practicable. (Although the NCP exempts CERCLA sites from obtaining permits for on-site actions, all remedial actions as well as removal actions must identify and comply with the substantive provisions of the permit regulations that are determined to be ARARs.) Even if USACE fenceline monitoring program does not involve a Superfund site, most, if not all, of the ARARs probably apply.

To determine what regulatory limits are considered ARARs and whether they apply to a USACE site, the following information is needed:

- Air quality designation of the site's location (i.e., attainment, nonattainment, unclassified, or transport) for each National Ambient Air Quality Standard (NAAQS).

- Classification of each designated nonattainment area (i.e., marginal, moderate, etc.).

- Required control measures, including emission limitations and emissions offsets.

- Baseline emission estimates at the site and estimated (i.e., modeled) air pollutant emissions associated with site investigation and remediation activities.

Once obtained, this information can be used to identify the ARARs that are applicable to the site.

Many air regulatory programs may be identified as ARARs or could otherwise be applicable to USACE site investigations and remediations. Many of these programs are driven by the Clean Air Act (CAA), whereas others, especially at the State and local levels, are independently developed. These regulatory programs are described below.

(1) NAAQS. For each of the six Federal criteria pollutants (CO, Lead, NO_2, PM_{10}, Ozone, and SO_2), EPA has established primary and secondary NAAQS. The primary standards are designed to protect public

health with an adequate margin of safety, whereas the secondary standards are intended to protect public welfare (e.g., soil water, crops, vegetation, animals, property, and visibility).

NAAQS themselves are not enforceable. Instead, the emission standards that are developed to attain the NAAQS that are enforceable. These emissions standards are generally incorporated into the State Implementation Plan (SIP) prepared by each State. In addition to emission standards, a SIP may include monitoring, recordkeeping, enforcement, and other requirements as well as measures such as economic incentives. All of the elements within a SIP are enforceable and, thus, would constitute ARARs.

Although not enforceable, CERCLA allows requirements such the NAAQS to be used as other criteria or guidelines to be considered (TBC) on an appropriate basis. For example, in cases where a SIP does not specifically address a criteria pollutant emission at a site, the pollutant's NAAQS can be used to derive acceptable emission or exposure levels. However, such use must be justified on the basis of protecting public health or the environment.

(2) Other potential standards.

(a) Resource Conservation and Recovery Act (RCRA) Standards. Regulations under RCRA address air pollutant emissions from several activities that may occur at CERCLA sites, and these regulations may be considered ARARs. Examples of affected activities include hazardous waste incineration; hazardous wastes burned in boilers and industrial furnaces; other thermal treatment operations; waste pile, land disposal, and landfill operations; hazardous waste treatment, storage, and disposal facilities; air stripping; and containment buildings.

(b) Non-Attainment Areas. To construct a major new source in an area not attaining a NAAQS, the owners or operators must ensure a net decrease in emissions in the area. Thus, existing sources must agree to reduce their emissions below that which would otherwise be required for them to offset the anticipated new emissions from the proposed new source. Additionally, the new source must apply lowest achievable emission rate (LAER) emission control technology. Also, under a SIP, existing sources in non-attainment areas may be required to apply reasonably available control technology (RACT). Under certain circumstances, both LAER and RACT may be ARARs for CERCLA sites meeting the definitions of major and new.

(c) Prevention of Significant Deterioration (PSD) Areas. For areas that are attaining NAAQS levels, the PSD program allows industrial growth while ensuring that air quality will not significantly deteriorate in these areas. To achieve this objective, the application of best available control technology (BACT) is required for new source construction and major modifications. PSD requirements would be considered ARARs in cases where a CERCLA action involves a major source or modification located in (or possibly upwind of) an attainment area.

(d) Title V Operating Permits Program. The 1990 CAAA require that states develop an operating permits program that incorporates all air emission permit requirements for major sources into a single permit for an industrial source. Examples of applicable permit requirements would be NESHAP, NSPS, MACT, and state-specific requirements (e.g., associated with a SIP). Although CERCLA on-site actions are not subject to administrative procedures and permit requirements, CERCLA sites will have to comply with any substantive standards associated with the permit programs that are determined to be ARARs.

(e) State Air Toxics Regulations. Some state air pollution control agencies have developed their own regulations for controlling air toxics emissions. These regulations are likely to be considered ARARs for most CERCLA sites. Because requirements differ widely from state to state, the rules for the state where the site is located must be carefully examined.

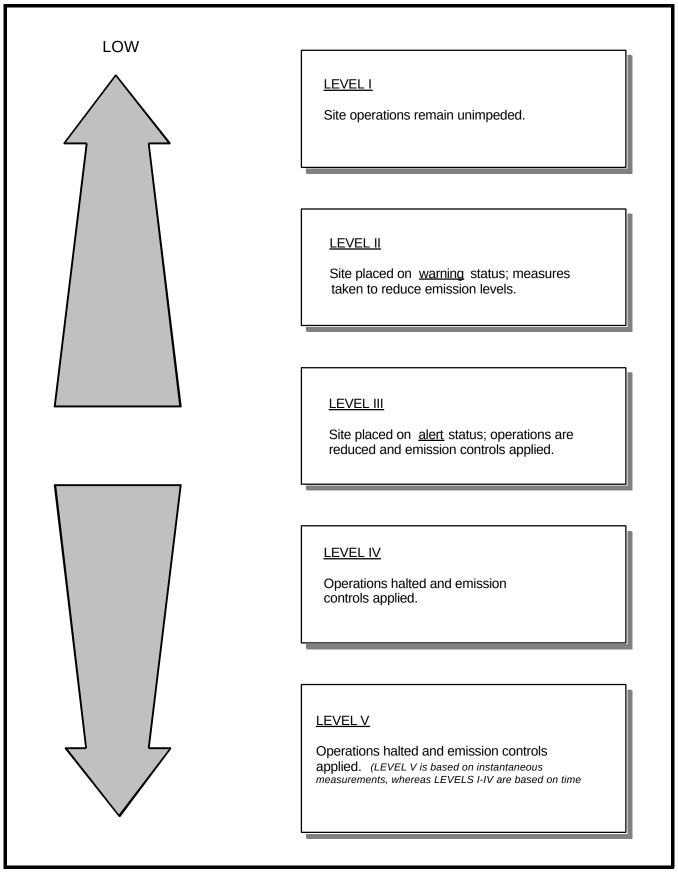
c. Action levels. Action levels are derived from regulatory limits and/or health exposure criteria and are intended to provide an exposure concentration level below which exposure is safe. In situations where the action level is exceeded (i.e., exposure occurs at unsafe levels), some action is required, such as shutting down the operation and/or removing personnel from the site until the problem is resolved. Because action levels are not regulatory limits, they are not ARARs. Instead, they are exposure levels that are established on a case-by-case basis and may differ from site to site, depending on the pollutants of concern and the potential for exposure to the workers and the public.

Action levels are usually established for two exposure scenarios: (1) the immediate working area within the site and (2) the fenceline (i.e., property boundary) of the site. The action levels associated with the working area are designed to protect the health of the on-site workers, whereas the perimeter action levels (PALs) associated with the fenceline are designed to protect the surrounding population and environment. (The fenceline is assumed to represent worst-case exposure for persons in nearby homes, businesses, and other public access areas.) Several time-averaging periods may be applied, depending on the time period associated with the applicable action level or ARAR, the specific compounds present and their health effects, and the capabilities of the air monitoring equipment. Typical averaging periods include 15-minute, 1-hour, 24-hour, 1-month, and 1-year averages, and instantaneous values.

Three types of action levels are often specified, based on the compounds of interest, the operating life of the source, the type of emission sources, and the potentially exposed population. These levels are described below:

(1) <u>Long-term action levels for carcinogens</u>. Long-term action levels for exposure to human carcinogens are usually based on inhalation unit risk factors published by EPA. The duration of exposure is generally assumed to be the expected operating life of the source or 30 years, whichever is less, and receptors are usually assumed to be constantly present during this period. The level of risk that is generally considered to be acceptable is in the range of 10^{-6} to 10^{-4} as an upper limit for the lifetime of the remediation effort. (A 10^{-6} risk represents a 1 in 1 million chance that a representative individual who is continuously exposed to site emissions will develop cancer over a lifetime.)

(2) <u>Long-term action levels for non-carcinogens</u>. Long-term action levels for non-carcinogenic effects are usually based on chronic reference concentrations (RfCs), which are estimates of the level of continuous exposure that can occur without adverse health effects during a person's lifetime. Chronic oral reference dose (RfD) values can also be used to derive action levels; however, care must be taken in extrapolating oral data to inhalation scenarios.


LOW
LEVEL I
Site operations remain unimpeded.
LEVEL II
Site placed on warning status; measures taken to reduce emission levels.
LEVEL III
Site placed on alert status; operations are reduced and emission controls applied.
LEVEL IV
Operations halted and emission controls applied.
LEVEL V
Operations halted and emission controls applied. (LEVEL V is based on instantaneous measurements, whereas LEVELS I-IV are based on time

- Greater specificity in contaminant analysis.
- Correlation of analytical and meteorological data to evaluate source direction.
- Calculation of net upwind/downwind concentration.
- Investigation and documentation of probable causes of exceedance.
- Implementation of site management controls, if necessary.

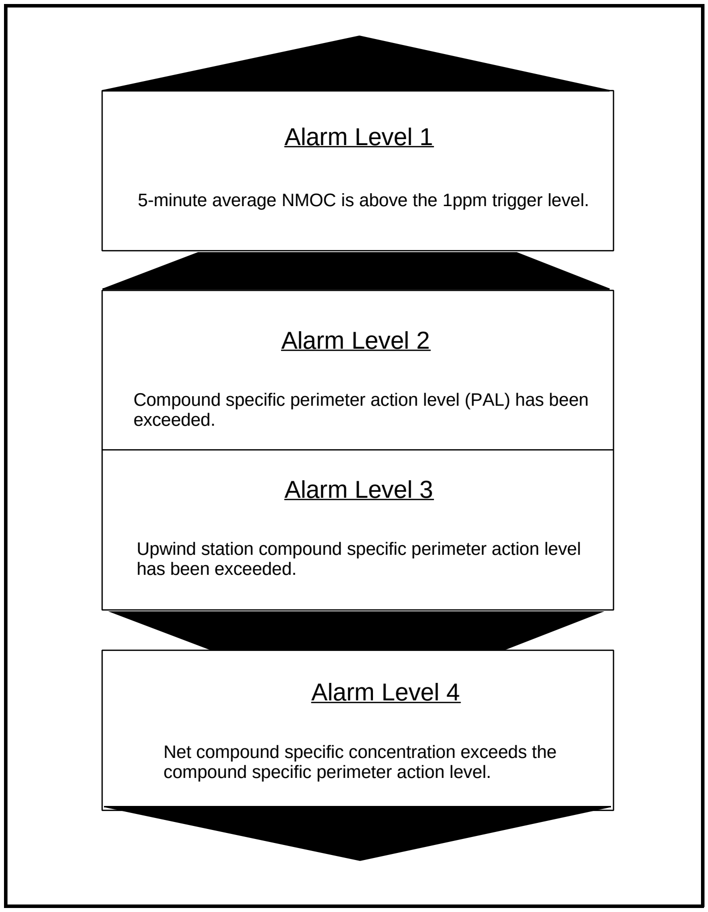


Figure 3-3. Example of site-specific alert levels involving NMOC and speciated organics, associated with an FFMS at HTRW sites

Alarm levels for all target analytes are preprogrammed within the gas chromatograph microprocessor as are the sampling and rest intervals. During any sampling interval, exceedances of either a total non-methane organic compounds threshold and/or specific target analyte thresholds may be determined depending on the specific mode of chromatograph operation. In operation, the microprocessor should cycle through the established sampling schedule, log the individual instrument measurements to the data storage system, and compare the measurements with the preset alert levels. When an exceedance is identified, the microprocessor should trigger audible alarm mechanisms within the analytical center and generate a report as well as initiate further analyses, data storage, and data correlation. An example “quickscan/speciated” operational scheme is described in the following sections.

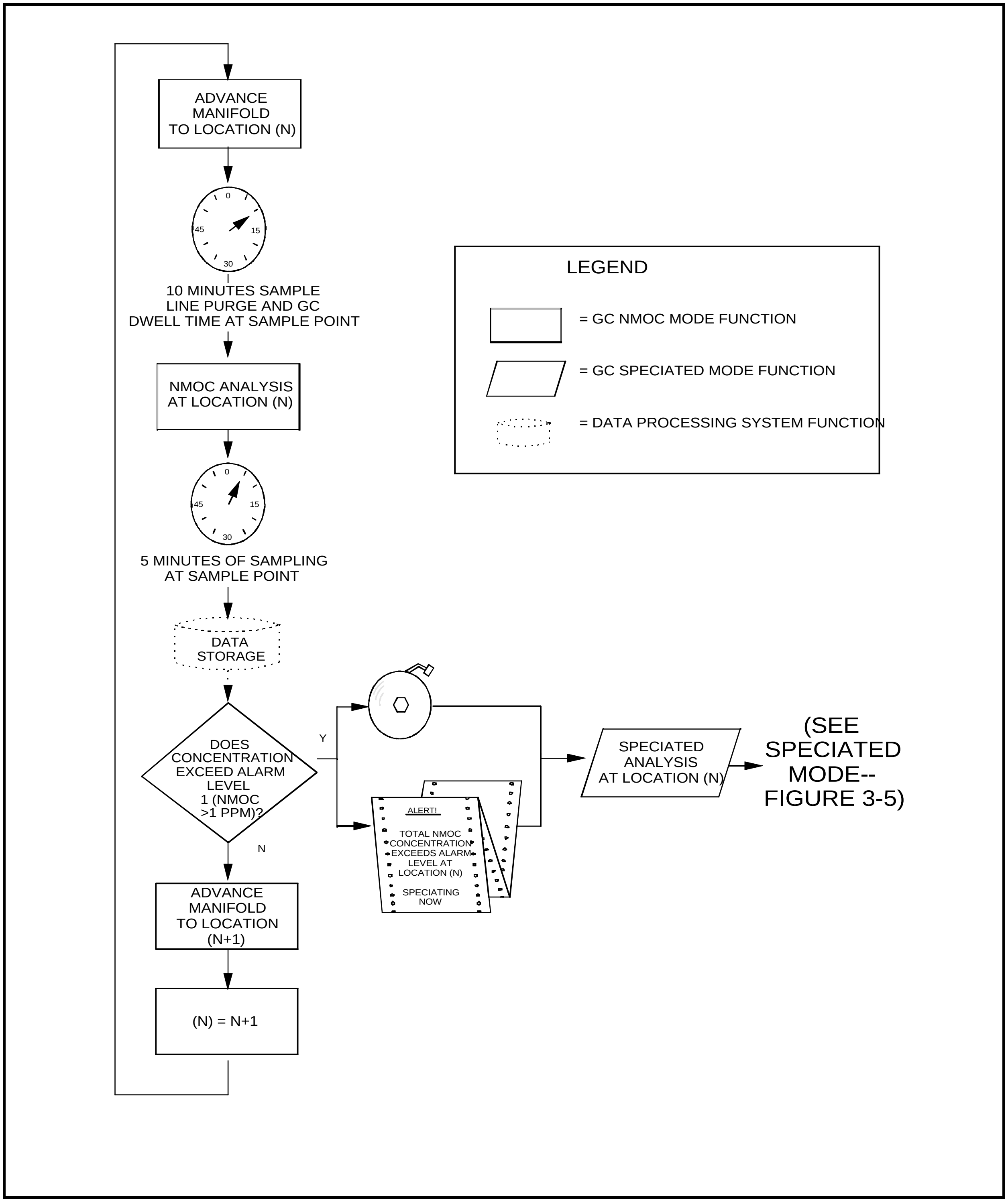


Figure 3-4. Example of decision for alarm level 1, NMOC mode

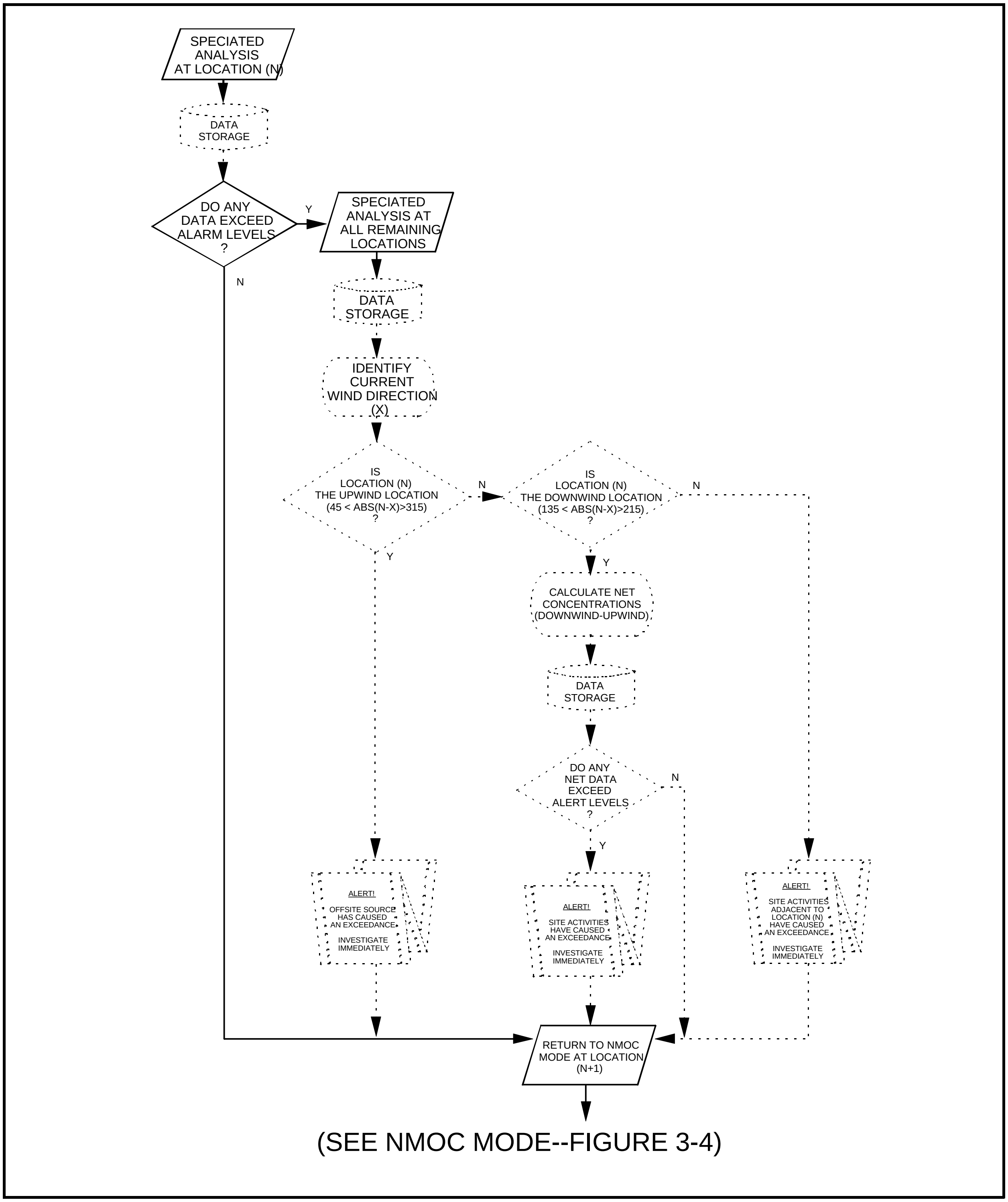


Figure 3-5. Example of decision for alarm levels 2, 3, and 4, speciated mode.

(1) Alarm level 1 — NMOC exceedance. The network of heated sample lines transport sample gas from locations around the waste site to the manifold sampling apparatus and the gas chromatograph. The microprocessor controlled manifold apparatus allows sequential sampling of each sample line. During routine sampling, the gas chromatograph is typically operated in a "Rapid Analysis Mode (RAM)" mode for total NMOCs. As such, the GC column is bypassed, and sample gas from each sample line is isolated and directed to an appropriate GC for gross quantification. Resultant data are automatically logged to the data storage system. When the total NMOC concentration in a given sample is below the alarm level, manifold apparatus simply proceeds to the next sample line. When total NMOC concentration exceeds the preset alert Level 1, the microprocessor generates a written report, and a speciated analysis of the sample is typically initiated, as illustrated in Figure 3-4.

(2) Alarm level 2 — compound specific exceedance. In the speciated mode, the sample gas is directed to the GC column wherein a gas chromatographic separation is performed. Individual contaminants elude from the GC column and are directed to a second GC detector for quantification. Specific analytes are identified on the basis of chromatograph retention time as compared to regular, multi-point calibrations of the system. Again, all data are logged to the data storage system. If the concentrations of all of the target compounds are below the preset alarm Level 2, the microprocessor signals the manifold apparatus to proceed to the next sample line, and analytical operation is shifted back to the RAM mode. If the concentration of any target compound exceeds the preset alarm Level 2, the microprocessor typically generates a report and initiates a sequence of speciated analyses of sample gas from each of the remaining sample lines. All resultant data are logged to the data storage system. Once a complete circuit of speciated analyses has been completed, the microprocessor signals the manifold apparatus to proceed to the next sample line and shifts analytical operation back to the RAM mode, as illustrated in Figure 3-5.

(3) Alarm level 3 — meteorological data evaluation and upwind compound specific exceedance. Subsequent to the speciated analysis for each sample line, the microprocessor queries the data storage system to determine the location of the upwind sample line. If the concentration of any target compound at the upwind location exceeds the preset alarm Level 3, the microprocessor typically generates a report indicating further investigation with a portable organic vapor analyzer in the area of the exceedance if necessary.

(4) Alarm level 4 - meteorological data evaluation and compound specific exceedance (net concentration). If the concentration of all target compounds at the upwind location are below the preset alarm Level 3, the microprocessor typically subtracts the upwind concentrations from those reported for the downwind line to determine the net concentrations. If the net concentration of all target compounds at the downwind location are below the preset alarm Level 4, the microprocessor typically generates a report indicating that no response is necessary. If the net concentration of any target compound at the downwind location exceeds the preset alarm Level 4, the microprocessor typically generates a report indicating the necessity for further investigation with a portable organic vapor analyzer in the downwind area.

3-4. EPA's Air Pathway Analysis (APA) Mechanism

a. Introduction. The primary motivations for clean-up of HTRW sites are to protect the general environment and to protect the health and safety of persons in proximity to the site. Contamination at a given HTRW site may pose a current or future risk by exposure from direct contact with the in-situ pollutants, subsurface migration of the contaminants via vapor plumes or ground-water plumes, contamination of surface waters, and atmospheric transport (and deposition) of gaseous, aerosols, or wind-blown contaminants. To successfully assess and clean up an HTRW site, it is necessary to characterize the potential effects of pollutant transport via the applicable exposure pathways for each step of the assessment and clean-up process.

b. Superfund process. Superfund sites are potential sources of air emissions that can impact onsite/offsite health and safety. Therefore, it is important to identify site-specific air emission sources and conduct follow-up air pathway analyses to characterize the potential impacts. The Superfund process consist of three (3) phases as identified in Figure 3-6. They are:

- Pre-remediation.
- Remediation.
- Post-remediation

Air emissions can occur during all phases of site investigation.

(1) Pre-remediation phase. The pre-remediation phase is concerned with evaluating the potential risk to public health and the environment posed by the Site. The pre-remediation phase begins with site discovery. From there, a Preliminary Assessment (PA) is conducted to collect as much information as possible about the pollutants present and their physical state. This activity is meant to be a relatively quick and inexpensive undertaking that involves collecting all relevant documentation about the site. The EPA uses the information gathered in the PA to determine if further investigation or action is warranted.

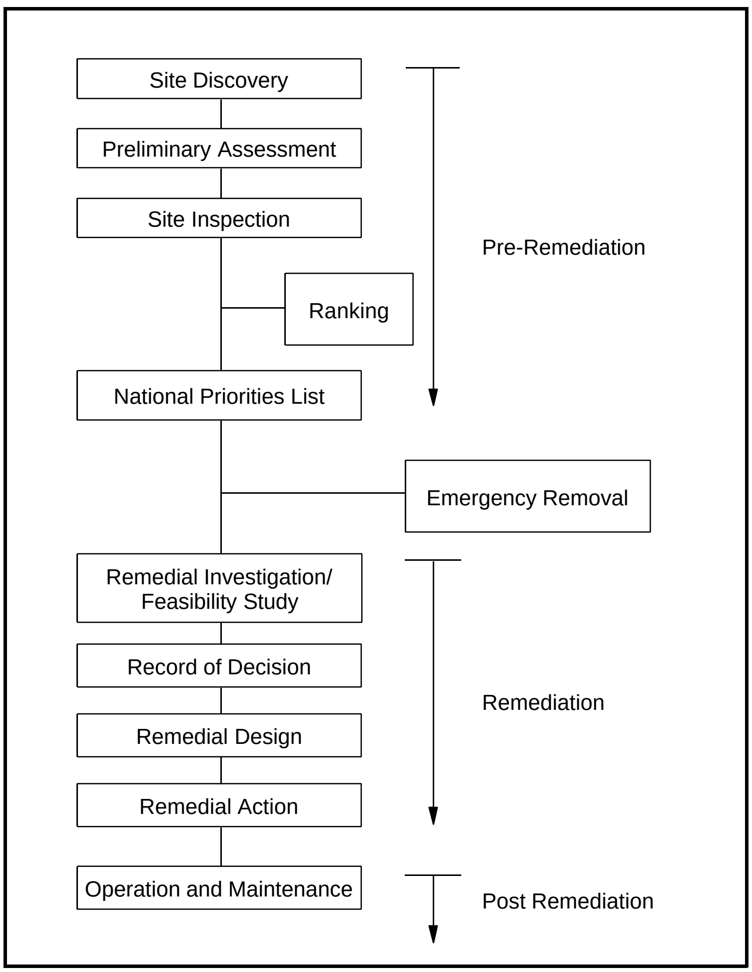


Figure 3-6. Example of EPA's air pathway analysis mechanism

If further investigation is warranted, a Site Inspection (SI) is conducted. The SI is the first action that involves some form of sample collection. This inspection is concerned with determining the immediacy of the health risk posed by the site. Samples are collected from the various media present and analyzed, and the results are used to rank the site within the Hazard Ranking System (HRS) model. The HRS model ranks the relative hazard the site poses over five pathways: air, direct contact, groundwater, surface water, and fire/explosion (the direct contact and fire/explosion pathways are evaluated but not currently included in the ranking). If the site scores higher than a predetermined amount, it is placed on the National Priority List (NPL).

Once on the NPL, the necessity of an Emergency Removal (ER) is evaluated via a site inspection by personnel from the Removal Program. This site inspection may take place during the Remedial Investigation (RI). If the site is believed to pose an immediate and significant health risk, actions are taken to ameliorate the problem. These actions may entail removing or covering exposed surface wastes, removing compressed gas cylinders, fencing the site to reduce public access, etc. Following the SI and emergency removal actions, if any, the remediation phase begins.

(2) Remediation phase. The remediation phase consists of the RI and Feasibility Study (FS), production of a Record of Decision (ROD), Removal Design (RD), and Remedial Action (RA). This phase lasts longer than the pre-remediation phase and is designed to take the site from a known health risk to a clean site in a controlled fashion. This phase is the main focus of USACE's activities at HTRW Superfund sites.

The RI and FS are separate steps but are typically conducted simultaneously and interactively. During the RI, data are collected to determine more precisely the types of compounds present at the site and the location and extent of contamination. The data gathered during the RI are used for any risk assessment that is performed. The data also are used to help identify appropriate cleanup procedures and remedial alternatives. The FS is concerned with identifying the preferred cleanup alternative. In making this identification, several alternative cleanup methods are considered and, when warranted, developed. Once the FS is completed, a ROD is issued, which serves as the official EPA decision about the preferred course of subsequent action.

The next actions are the design and implementation of the remediation alternative. The RD is detailed plan for site remediation, and the RA can take a variety of forms--from short-term activities to long-term activities that can take several years to complete.

(3) Post-remediation phase. Once the remedial activity has ended, a brief monitoring period takes place during which the effectiveness of the cleanup is determined. This period is called the post-remediation phase; it may also be referred to as the Operations and Maintenance (O&M) phase. If the monitoring shows that the site no longer poses a health or environmental threat, the site may be removed from the NPL.

c. Air pathway analysis. The evaluation of these emissions are part of EPA's APA's for quantifying emissions associated from a site during all stages of remediation. An APA is a systematic approach involving a combination of modeling and monitoring methods to assess actual or potential receptor exposure to air contaminants. Therefore, an APA is an exposure assessment for the air pathway, and it provides input to the Superfund risk assessment process. The primary components of an APA are:

- Characterization of air emission sources (e.g., estimation of contaminant emission rates).
- Determination of the effects of atmospheric processes (e.g., transport and dilution).
- Evaluation of receptor exposure potential (i.e., what air contaminant concentrations are expected at receptors of interest for various exposure periods).

The overall goal of an APA is to evaluate the site's actual or potential effects on air quality. The specific goal of any associated air monitoring network is typically to evaluate the exposure of on-site workers and the off-site population and surrounding environment.

CERCLA and SARA mandate the characterization of all contaminant migration pathways from the waste or hazardous material to the environment and evaluation of the resulting environmental impacts. However, air pathway analyses are often overlooked because many sites have little or no perceptible air emissions in their baseline or undisturbed state. Even low-level emissions, however, may be significant if toxic or carcinogenic compounds are present. From a health-risk perspective, the dominant exposure pathway over the lifetime of a site will, in many cases, be due to air exposure during remediation. Failure to perform an adequate air pathway assessment may result in an underestimate of the risk posed by the site and, in some cases, can ultimately result in work stoppages, added costs, and public relation problems.

Air pathways have several unique characteristics. Most other pathways require extended time periods for exposure to first occur, and exposure can be minimized by limiting site access (e.g., by putting a fence around the site) or by getting local residents to forgo use of contaminated resources. With the air pathway, however, any on-site releases of emissions can have an almost immediate downwind impact. The point(s) of impact can change relatively quickly as the wind direction and wind speed shift; therefore, the effects of atmospheric plumes may cover a wider area than those of groundwater plumes. If local residents are within an air emission plume, they have little choice but to breathe the air. The exposure rate, however, may vary greatly from receptor to receptor. The factors cited above cause, in many cases, exposure via the air pathway to be harder to predict than exposure via other pathways.

The potential for air releases from a site can be difficult to determine in some cases. If unplanned-for air releases occur during remediation activities (e.g., the release of subsurface pockets of toxic gases), it may be necessary to suspend remediation activities until further site investigation or remedial design work can be completed to address air emission concerns. Such delays can be costly and also may affect the public's confidence in the selected remediation approach.

(1) Evaluate exposure of on-site workers. On-site workers at a hazardous waste site may be exposed to significant amounts of air pollutants in the course of performing their jobs. Any source of emissions at a site will result in an emissions plume. Fugitive air emission releases usually occur at ground level and are not thermally buoyant; therefore, the maximum ambient air concentrations for such sources occur immediately downwind of the source and at ground level. Point sources, such as Soil Vapor Extraction (SVE) units, can have relatively short stacks and nonbuoyant plumes which can result in the maximum ground level ambient air concentrations from such sources occurring within the site boundaries. Frequently, on-site workers may have to operate equipment or otherwise work in contact with such emission plumes.

(2) Evaluate pollutant levels at fenceline and exposure of off-site community/environment. A major concern at hazardous waste sites is the potential exposure via the air pathway of residents and workers in the areas surrounding the site. The degree of concern depends on the nature of the contamination, the proposed remedy, and the proximity of the off-site populace (receptors). The exposure of off-site receptors typically is evaluated in several steps in the APA process, and both modeling and monitoring approaches may be employed as part of the exposure assessment.

The evaluation of human exposure (due to inhalation) using a monitoring approach generally involves measuring the concentrations of target analytes at the fenceline of the site for ground-level emission sources and at the areas of maximum estimated ground-level impacts for elevated emission sources (e.g., incinerator stacks). Additional ambient air monitoring may be conducted at selected receptor locations in the surrounding community (e.g., at nearby schools) or on-site, if there is public access. Data is also usually collected at locations upwind and downwind of the site. The data are compared with action levels to determine if there is cause for concern at downwind locations. If downwind concentrations exceed levels of concern, actions must be taken to reduce pollutant emissions. The difference in the concentrations measured downwind and upwind of the site yield adjusted concentrations considered to represent the contribution of the site emissions to the local air quality.

The evaluation of off-site exposure generally requires that monitoring be performed whenever significant air emissions may be released from the site. At sites that have the potential for adversely affecting the air, this requirement is often addressed by performing a short baseline study prior to remediation, followed by continuous monitoring during remediation. Usually, a fixed network of point samplers is located around the perimeter of the site, samples are collected continuously, and all samples are analyzed. Additional samplers may be located near the working areas. The number of samples and their placement is therefore important to ensure that emissions are properly characterized, which requires a basic understanding of the sources of the emissions at the sites and their mechanisms for release and subsequent impact to the surrounding community.

3-5. Chemical and Physical Properties of Hazardous Air Pollutants (HAP)

a. Air emission mechanism from HTRW sites. Emissions from HTRW sites may be classified as either point or area sources. Point sources include stacks (process emissions) while area sources are generally associated with fugitive emissions (e.g., from landfills, lagoons, material handling and contaminated surface areas).
Air contaminant emissions can be classified into two basic categories (i.e., gas phase emissions and particulate matter emissions). The emission mechanism associated with gas phase and particulate matter releases are quite different.

(1) Gas phase emissions. Gas phase emissions primarily involve organic compounds but may also include certain metals. Gaseous emissions from an HTRW site can be released through a variety of mechanisms, including:

- Volatilization.

- Biodegradation.
- Photodecomposition.
- Hydrolysis.
- Combustion.

Volatilization is typically the most important mechanism for air releases and occurs when molecules of a dissolved or pure substance escape to an adjacent gas layer. For wastes at the surface, this action results in immediate transport into the atmosphere. Volatilization from subsurface wastes results in a concentration gradient in the soil-gas from the waste to the surface. The rate of emissions is usually limited by the rate of diffusion of contaminants to the soil-air interface. Volatilization is thus an important process for the release of gaseous emissions from both surface contamination and contaminants in the shallow subsurface. The rate of volatilization of contaminants at a soil-air boundary is a function of the concentration and properties of the escaping chemical, soil properties (moisture, temperature, clay content, and organic content), and properties of the air at soil level (temperature, relative humidity, and wind speed). The rate of volatilization from liquid surfaces is dependent on the concentration of the contaminants in the boundary layer of liquid at the liquid-air interface. Any factors that enhance mixing in the bulk liquid and replenishment of contaminants in the boundary layer will enhance the volatilization rate.

(2) Particulate emissions. Particulate matter (PM) emissions from hazardous waste sites can be released through wind erosion, mechanical disturbances, and combustion. Hazardous substances, such as metals, can also be adsorbed onto particulate matter and thereby transported with the inert material.

The importance of each of these mechanisms varies as a function of source type. The hazardous constituents of concern in a particulate release may involve constituents that are either absorbed or adsorbed onto the particulate or constituents that actually comprise the particulate. These constituents may include volatile and semi-volatile organic compounds, metals, and non-volatile toxic organic compounds.

Significant atmospheric dust can arise from the disturbance of soil exposed to the air. Dust generated from these area sources is referred to as “fugitive” because it is not discharged to the atmosphere in a confined flow stream. The dust generation process is caused by two basic physical phenomena: entrainment of dust particles by the action of wind erosion of an exposed surface under moderate-to-high wind speeds, and pulverization and abrasion of surface materials by mechanical disturbances.

For airborne particulates, the particle size distribution plays an important role in inhalation exposure. Large particles tend to settle out of the air more rapidly than small particles, but may be important in terms of non-inhalation exposure. Very small particles (i.e., those that are less than 10 microns in diameter) are considered to be respirable and thus present a greater health hazard than the larger particles.

(3) Transport and diffusion. Once released to the ambient air, a contaminant is subject to simultaneous transport and diffusion processes in the atmosphere. Atmospheric transport/diffusion conditions are significantly affected by meteorological, topographic, and source factors.

The contaminant will be carried by the ambient air, following the spatial and temporal characteristics of the wind flow field (as determined by wind direction and speed conditions). The turbulent motions of the atmosphere (as characterized by atmospheric stability conditions) promote diffusion of airborne gases and particulate matter. Thus, the local meteorology during and after the release determines where the contaminant moves and how it is diluted in the atmosphere.

(4) Transformation, deposition, and depletion. Contaminants emitted to the atmosphere are subjected to a variety of physical and chemical influences. Transformation processes can result in the formation of more hazardous substances, or may result in hazardous constituents being converted into less harmful ones. A variety of inorganic and organic materials may be present along with the natural components of the air. The emissions may remain in the atmosphere for a considerable time and undergo a myriad of reactions. Both primary and secondary products are exposed to further changes through oxidation and photochemical reactions. In general, however, these effects are secondary to transport and diffusion in importance and are subject to more uncertainty.

b. Defining hazardous air pollutants. Ambient air around a hazardous waste site is a very complex, dynamic system of interacting chemicals. As previously discussed, the pollutants can be found in the gas phase, in the particulate phase, or in a liquid aerosol surrounded by a gaseous atmosphere. The complex nature of the dynamic air system around a site controls the complexity of the solution of sampling method and analytical requirements in the identification and quantification of these chemicals. Each pollutant has its own unique characteristics, yet many fall within basic classes such as volatiles, semi-volatiles, aromatics, halogenated compound, etc.

(1) Volatile organic compounds. VOC is a general term used to describe the gaseous nonmethane organic emissions from a hazardous waste site. These compounds have vapor pressures greater than 10^{-1} mm Hg and boiling points <200 C and, thus, are predominantly found in the gaseous state in the atmosphere, as identified in Table 3-1, and illustrated in Figure 3-7. Much of the present work dealing with samples and analysis or organic compounds from hazardous waste sites has been done on VOCs utilizing SUMMA® whole air canisters followed by or utilizing on-site real-time analyzers that separate and quantify the individual organic constituents by gas chromatography/flame ionization detection (GC/FID).

Table 3-1
Defining Hazardous Air Pollutants

Category	Vapor pressure, mm Hg	Boiling point, C
• Particulate matter	$<10^{-7}$	>500
• Semi-volatile compounds	10^{-1} to 10^{-7}	200-500
• Volatile compounds	$>10^{-1}$	<200

(2) Semi-volatile organic compounds. Semi-volatile organic compounds (SVOC) are not as easily collected or analyzed as the VOCs. However, attention has been focused at resolving the problems associated with SVOCs found around hazardous waste sites. Members of this class include polynuclear aromatic hydrocarbons (PAHs) with four or fewer fused rings; halogenated compounds such as polychlorinated

biphenyls (PCBs); organopesticides with chlorine and phosphorus; and various pesticides and herbicides. Vapor pressures of these compounds range from 10^{-1} to 10^{-7} mmHg. These less volatile compounds are present in the atmosphere, both in the gaseous phase and in a particle-bound phase. Sampling from this type of pollutant usually involves a filter followed by polyurethane foam (PUF) or XAD-2 resin in a high-volume sampler.

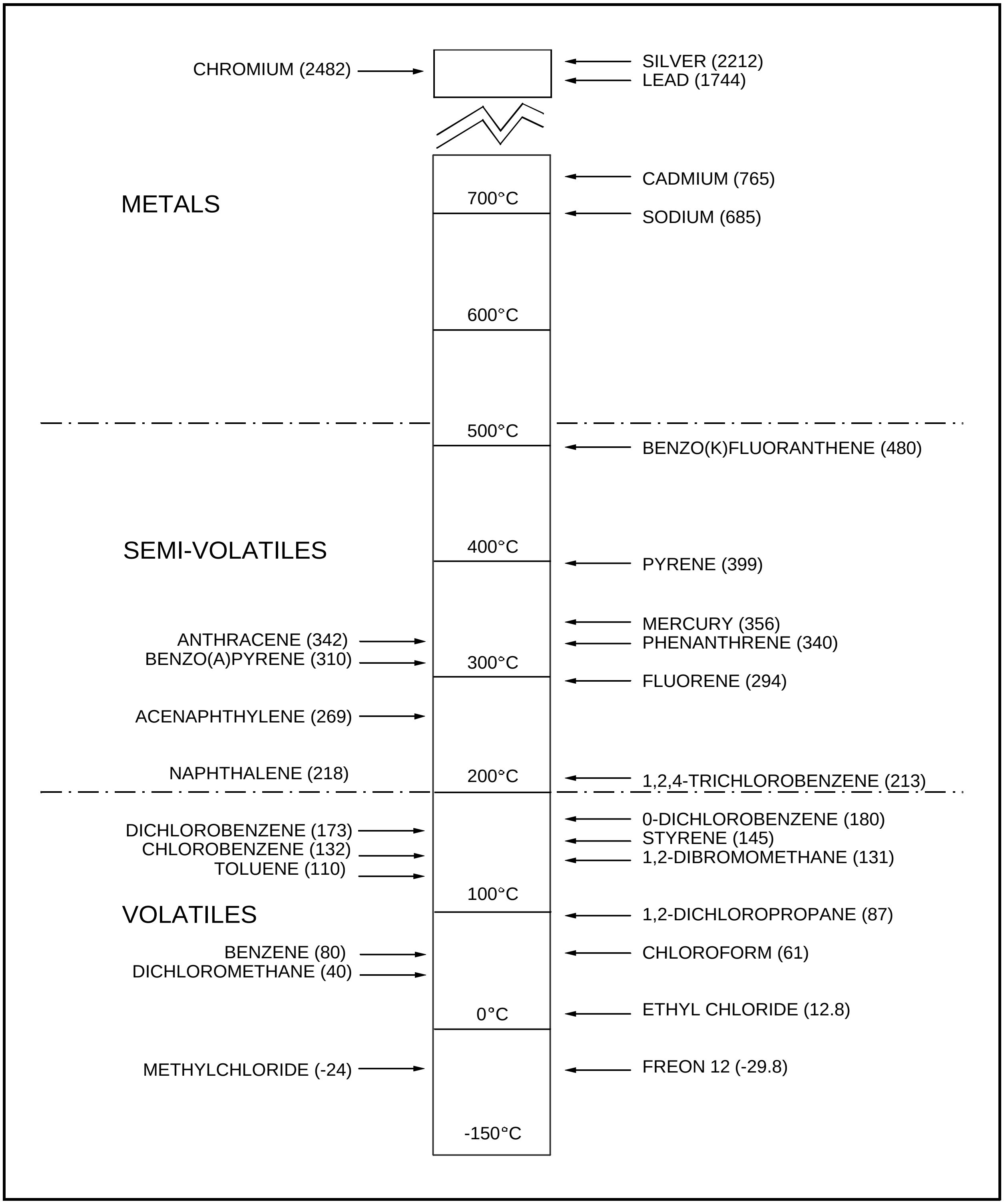


Figure 3-7. Example of EPA's defining hazardous air pollutants by boiling point.

(3) Non-volatile organic compounds. Ambient air contains relatively low amounts of non-volatile organic compounds, which are organic compounds with vapor pressures less than 10^{-7} mmHg. These compounds are almost always found in the condensed particle-bound state. Polynuclear hydrocarbons with more than four rings, their nitrogenous and oxygenated derivatives, are the major constituents of this category. A high-volume sampler containing a quartz filter is used to monitor non-volatile organic compounds.

(4) Inorganic compounds. Inorganic compounds are those compounds with vapor pressure less than 10^{-12}mm Hg. These compounds are almost always found in the particle state. Heavy metals, such as lead, chromium, cadmium, zinc, beryllium copper, and other earth metals represent this category of HAPs. Once again a high-volume sampler containing a quartz filter is used to monitor inorganic compounds.

c. Technology for monitoring hazardous air pollutants at HTRW sites. A variety of sampling methods can be used to monitor hazardous air pollutants at HTRW sites. The methods vary according to sample type (i.e., volatile compounds, semi-volatile compounds, inorganics, and particulate borne compounds), sample duration and detectability, and applicability to the monitoring objectives of the program. The greatest number of available methods for any one type are for the volatile fraction. Semi-volatile pollutants exist in both the vapor and particulate phases, so the sampling methodology must address both. Finally, the concentration of particulate-borne contaminants (inorganic and non-volatile organic) can be monitored by collection of the total mass loading during sampling.

Sampling techniques may be divided into these broad classes, regardless of the analytes of concern. They are time-integrated sampling, grab sampling and real-time monitoring.

- **Time-Integrated sampling--**time-integrated sampling involves collecting a sample over a fixed time period (e.g., 8- hour or 24-hour) and provides a single, integrated value. Methods included in time integrated are whole air canister sampling, solid adsorbent tube monitoring, and most particulate matter and semi-volatile collection systems.

- **Grab sampling--**grab sampling involves collecting an instantaneous air sample. This technique usually requires some form or type of container to contain the instantaneous sample.

- **Fixed-site real-time monitoring--**real-time monitoring involves sample extraction, conditioning, analyzing, and reporting within a fixed time period, usually less than 15 minutes.

- **Passive sampling--**passive sampling involves collecting a sample over an extended period of time without assistance from a pump. This sampling techniques is usually exclusively associated with monitoring volatile organics.

- **Portable real-time monitoring--**portable GC systems provide sampling and analysis of a limited target compound set. The use of portable systems allows one to “survey” the site and identify “hot spots,” thus making it a very feasible tool during investigating phase of a site.

Each of these sampling techniques has certain advantages and disadvantages, depending on the monitoring objectives, the required detection limits, and the duration of the monitoring program. The different techniques are described below.

(1) Grab sampling. Grab sampling involves extracting a sample at a single point-in-time. As discussed earlier, the hardware for accomplishing this sampling is usually a whole air sample container (i.e., SUMMA® canister, glass sampling bulb, tedlar bags, or solid adsorbent tubes for colorimetric gas detection). In the grab sample mode, a sample is taken over a very short period of time, from a few seconds to a few minutes.

Grab sampling is usually used in EPA's APA program as a screening technique to identify contaminants that might be present in an area of interest and to determine their approximate concentration. As an example, grab sampling can be used to collect volatile organics during the site investigation stage using tedlar bags or SUMMA® canisters to help develop the target compound list for future long-term monitoring or to assess the preliminary risk at the site.

Some of the advantages of grab sampling are that the methodology is simple to apply and sampling costs are at a minimum. Several disadvantages, however, are associated with grab sampling. One major disadvantage is that the value acquired is a single point in time and cannot be related to typical ambient air regulations involving 8- and 24-hour limits. Another disadvantage is that the sample volume acquired is relatively small, thus requiring very sensitive analytical techniques if the data is to be used for comparison with ambient air regulatory limits. Finally, inward and outward diffusion of gases in some of the collection containers has been observed, thus creating uncertainty in the data.

(2) Time-integrated monitoring. This category of monitoring is the most commonly used technique in monitoring HAPs at HTRW sites. Time integrated is most applicable if the pollutant is present in very low concentrations because sampling can be conducted long enough to provide the analytical system sufficient sample to meet required detection limits. Appropriate time-integrated sampling techniques are available for collecting volatiles, semi-volatiles, inorganic, and particulate matter (PM) in the ambient air.

In time-integrated sampling, the sampling period can be as short as minutes or as long as weeks or months, depending upon the detection limits needed to be reached associated with the analytical system. The results from the analysis of integrated samples are expressed as average concentrations over the sampling period.

Integrated sampling for PM can be accomplished by means of total suspended particulate (TSP) samplers, dichotomous samplers, or size-select inlet samplers. The sophistication of the samplers ranges from manually operated hand-held units to fully automated units that can run for weeks unattended.

Integrated sampling for gaseous pollutants can be accomplished by extracting a sample over a period of time through solid adsorbents, SUMMA® canisters, impingers, or other collection devices that can capture the analytes of interest over a period of time. In general, the greater the sampling time the more analyte is trapped on the collection media, thus allowing for lower detection limits. Thus, integrated sampling methods may not be adequate for evaluating compliance with short-term (e.g., 15-minute, 1-hour) action levels. As an example, a high-volume particulate monitor may not be adequate to determine compliance with a 1-hour emission limit for selected inorganic metals. Integrated sampling methods are therefore useful for determining pollutant concentration when the regulatory limit is based on a time similar to the 8-hour PEL or EPA's 24-hour NAAQS. For some analytes, like dioxins, a sampling period of 72 hours may be required to obtain adequate sample to meet desired detection limits.

Integrated sampling techniques offer additional advantages. They can be cost effective, require fewer personnel than continuous monitoring and are sufficiently flexible to achieve the detection sensitivity to meet the health base detection limits needed in most regulatory monitoring programs. In addition, samples can be analyzed at a more convenient time or place off-site. Several drawbacks of integrated sampling include the lack of immediate feedback on the data that is acquired, thus preventing modification of remediation activities on site. In addition, time-integrated sampling methods typically do not give site decision makers timely data so that they can determine worker and community exposure to pollutants or the need for implementing emission controls. Another disadvantage is that short term temporal information is also lost. Finally, time-integrated monitoring requires the collected sample to be transported to another location for analysis, thus leading to possible sample integrity problems involving sample deterioration, losses of analytes, and contamination for the surround environment.

(3) Real-time monitoring. Real-time monitoring refers to methods that provide nearly instantaneous values, thus allowing multiple measurements over a very short time period of several minutes. In general, real-time means the ability to extract, condition, concentrate, analyze, and report data nearly instantaneously. The samples may be analyzed directly at the collection point, or the sample may be transported through hundreds of feet of heat-trace lines to a central analytical center for analysis. In the former situation, a single analytical system is used at each of the sampling points around the site. In the latter case, a single analytical device is used to analyze samples from multiple sampling points around the site. In this case, the analytical system cycles through each of the sampling points in the network. Automated analytical systems may involve GC, GC/MS, mass spectrometry/mass spectrometry (MS/MS), infrared spectroscopy (IR), fourier transform infrared spectrometry (FTIR), or open-path optical monitoring (OPOM).

The use of real-time monitoring usually occurs when site regulatory personnel must make timely decisions on the emissions from the site during periods of active remediation. Real-time monitoring also enables the regulators to "see" peak short-term concentrations that may have important health effects associated with site remediation. Variations in concentration as a function of time can be correlated with source emissions. The major advantage that real-time monitoring has over portable real-time monitors is that most portable monitors react with entire classes of compounds and tend not to be specific for a given compound that might be on the target compound list. As an example, photoionization detectors (PID) are very sensitive to aromatic hydrocarbons but significantly less sensitive to aliphatic hydrocarbons. In essence, if the portable system does not have a GC column attached to it, it does not have the capability to differentiate between the two compounds like the real-time monitoring system.

Although real-time monitoring systems have numerous benefits, they also have disadvantages. Such systems are expensive and require frequent calibration and routine maintenance. In addition, real-time systems are usually complex, requiring highly trained field personnel, rigorous quality-control (calibration) procedures, and independent performance audits of routine monitoring and data handling operations. Finally, securing electrical power and a suitable location for housing the real-time system and the adaptation of sampling lines and cables for the system can require long-term planning and entail considerable expenses.

(4) Passive sampling. In recent years, the development of passive sampling devices (PSD) has drawn much attention. These devices sample by means of gas diffusion or permeation of VOCs on an adsorbent (i.e., Tenax®, charcoal) rather than by means of a pump. They have been shown to be simple, convenient, inexpensive, and valid alternatives for assessing time-weighted average concentrations for personal exposure monitoring.

Analysis of adsorbed compounds on sampling tubes is accomplished by thermal desorption and chromatographic separation. Specificity can be introduced into a passive sampling technique by choice of a suitable adsorbent substrate which is unique to capturing a specific compound. As an example, a passive sampler using chemically-coated glass fiber filter has been developed for formaldehyde. A comparison of recoveries of trichloroethylene from active charcoal tubes and a thermal desorbable personal monitor revealed the passive sampler to exhibit better recovery efficiency. A personal dosimeter based on molecular diffusion and direct detection by room temperature phosphorescence has been developed to monitor vapors of polynuclear aromatics.

(5) Portable gas chromatographic sampling techniques. Probably one of the most attractive sampling and analysis approaches is that of portable sampling methods based upon real-time monitoring. Portable sampling techniques are mostly used in a “screening” application at HTRW sites during both pre-remediation and remediation activities. Portable monitoring allows instantaneous results to be acquired so on-site decisions can be made in the protection of workers and off-site communities. Portable monitoring allows rapid turn-around of data with relatively inexpensive instrumentation.

Two of the most common detectors utilized in portable gas chromatographics are portable FID and PID. These detectors, used in conjunction or separate, are generally used to give background levels of total VOC and to identify “hot spots” of VOCs within a test locale. Two of the most important attributes of these detectors are their ever-increasing levels of sensitivity, and when used in conjunction with a chromatographic column, the ability to specifically characterize and/or identify VOCs at the HTRW sites.

The operation of an FID portable GC involves the pollutant entering the flame where it is mixed with hydrogen and burns. Ions and electrons formed in the flame enter the electrode gap, decreasing the gap resistance, thus permitting a current to flow. The flow of electrons determines the pollutant concentration. The FID is a universal detector, responding to a whole host of organic compounds and classes. One of the major advantages of the FID is its lack of response to air and water. The FID therefore serves as a basis for most commercially available “total hydrocarbon” and “non-methane hydrocarbon” analyzers. The detection limits for most FIDs is 100 ppb.

Portable PIDs operate on the principle of photoionization. In operation, the gas stream is subjected to a high-intensity beam of ultraviolet (UV) radiation from a lamp of a particular energy. If the molecule ionization potential is lower than that of the lamp, absorption occurs by the gas molecule, leading to the formation of a positive ion and free electron. The positive ion is collected at the electrode and the resultant current is directly proportional to the analyte concentration.

Consequently, the ionizational potential of the lamp is very important in the detection of certain classes of compounds. Compounds having high ionization potential will be less easily detected than those of lower ionization potential. This ability allows one to readily detect aromatic hydrocarbons, but will not detect aliphatic hydrocarbons having a higher ionization potential.

The manufacturers of photoionization lamps usually provide lamps in four (4) energy levels. They are:

- 8.3 eV.
- 9.5 eV.
- 10.2 eV
.
- 11.7 eV.

It is more difficult to ionize an alkane (i.e., butane) than a chlorinated aromatic (i.e., chlorobenzene). The selection of the lamp therefore allows the user to "screen out" certain organics based upon their ionization potential. If the lamp does not have enough energy to ionize the molecule, it therefore does not "see" it. Consequently, aromatics can be selectively detected in the presence of halogenated hydrocarbons with a low-energy lamp (e.g., 9.5. eV), whereas both groups can be detected with a high-energy lamp (11.0 eV).

The sensitivity of the PID is considerably better than the FID in most cases (10 ppb or better). Recent models have shown sensitivity to the sub-ppb range.

d. Developing a site-specific target compound list (TCL).

(1) Introduction. The developing of a site-specific TCL is a key factor in the development of a FFMS for HTRW sites. HTRW sites often contain a complex mixture of contaminants, and not every contaminant will pose a significant risk via the air pathway. Selection of too broad a range of compounds can lead to excessive cost, whereas selection of too few may result in not meeting the project objectives. In most cases, the selection of a TCL at a HTRW site is a compromise between technical feasibility and environmental significance.

The objective of developing a site specific TCL is to provide a prioritized list of compounds for which there are sampling and analytical protocols, and as a tool for optimizing the air monitoring design. The TCL includes compounds most commonly found at the HTRW site which pose the most significant threat to human health and are most likely to enter the air pathway.

Certain compounds typically are considered to "drive" both the listing of target compounds and the risk assessment as part of the APA. These compounds pose the most significant risk during the remediation program. Consequently, the objective of the APA is to focus available resources and effort on those compounds thought to pose the most significant risk at a site, rather than including an evaluation of every compound found at the HTRW site. The selected analytes are sometimes referred to as target compounds or compounds of potential concern.

(2) Classification of target compounds. Compounds of interest for FFMS program are categorized, based on the compound and its physical and chemical properties, into four broad classifications, as discussed in Paragraph 3-5. The four classifications once again are:

- VOC, especially benzene and chlorinated solvents such as vinyl chloride, methylene chloride, chloroform, etc.

- SVOC, such as PCBs, PAHs, pesticides., and other semi-volatile inorganic compounds such as those containing mercury.

- Non-volatile compounds such as asbestos and cyanides.

- Heavy metals, such as lead, chromium, cadmium, zinc, beryllium, copper, and arsenic.

Table 3-2 summarizes the compound classes and the representative compounds in each class of the four classifications. Table 3-3 provides typical concentrations of the different categories of hazardous air pollutants in the atmosphere.

As previously discussed, an attempt to monitor all emissions at the HTRW site is not realistic. Consequently, the selection of target compounds to represent either a broad classification, or a specified class of compounds is usually performed in developing an air monitoring program at an HTRW site. The selection of target compounds (i.e., indicator compounds) at a minimum should include all contaminants with concentrations greater than or equal to 10% of the appropriate health based action level at the site. These contaminants are expected to represent the greatest contributors to potential health impacts. This approach provides a practical basis to address the large number of potential emission compounds at the site. Many factors should be reviewed in the decision process for selecting tracer species, including:

Table 3-2
Example Of Classification Of Organic And Inorganic Compounds For Air Monitoring At HTRW Sites

Contaminant type	Compound class	Representative compounds	
Volatile organics	Aromatics	benzene toluene ethylbenzene	total xylenes styrene chlorobenzene
	Halogenated species	carbon tetrachloride chloroform methylene chloride chloromethane 1,2-dichloropropane trans-1,3-dichloropropene cis-1,3-dichloropropene bromoform bromomethane	bromodichloromethane dibromochloromethane 1,1,2,2-tetrachloroethane 1,1,1-trichloroethane 1,1-dichloromethane chloroethane tetrachloroethane trichloroethane vinyl chloride
	Oxygenated species	acetone 2-butanone	2-hexanone 4-methyl-2-pentanone
	Sulfur containing species	carbon disulfide	

	Nitrogen containing species	benzonitrile
Volatile (inorganics)	Acid	hydrogen cyanide hydrochloric acid
	Sulfur containing	hydrogen sulfide

Table 3-2 (Continued)

Contaminant Type	Compound Class	Representative Compounds	
Semi-volatile organics	Phenols	phenol 2-methylphenol 4-methlphenol 2,4-dimethylphenol 2-chlorophenol 2,4-dichlorophenol 2,4,5-trichloropheno	2,4,6-trichlorophenol pentachlorophenol 4-chloro-3-methylphenol 2-nitrophenol 4-nitrophenol 2,4-dinitrophenol 4,6-dinitro-2-methylphenol
	Esters	bis(2-ethylhexyl)phthalate di-n-octyl phthalate di-n-butyl phthalate diethyl phthalate vinyl acetate	
	Chlorinated	1,2-dichlorobenzene 1,3-dichlorobenzene 1,4-dichlorobenzene 1,2,4-trichlorobenzene hexachlorobenzene	nitrobenzene 2,6-dinitrotoluene 2,4-dinitrotoluene 3,3-dichlorobenzidine
	Amines	n-nitrosodimethylamine n-nitrosodi-n-propylamine n-nitrosodiphenylamine aniline	2-nitroaniline 3-nitroaniline 4-nitroaniline 4-chloroaniline
	Ethers	bis(2-chloroethyl)ether bis(2-chloroisopropyl)ether	
	Alkadienes	hexachlorobutadiene hexachlorocyclopentadiene	
	Miscellaneous and aromatics	benzoic acid benzyl alcohol bis(2-chloroethoxy)methane dibenzofuran hexachloroethane isophorone	
	Polynuclear aromatic hydrocarbons (PAHs)	acenaphthene acenaphthylene benz(a)anthracene benzo(b)fluoroanthene benzo(k)fluoroanthene benzo(g,h,i)perylene benzo(a)pyrene chrysene dibenz(a,h)anthracene	fluoroanthene fluorene indeno(1,2,3-c,d)pyrene naphthalene 2-methylnaphthalene 2-chloronaphthalene phenanthrene pyrene
	Pesticides	alpha-BHC beta-BHC delta-BHC gamma-BHC heptachlor haptachlor epoxide 4,4'-DDT 4,4'-DDD 4,4'-DDE endrin	endrin ketone endrin aldehyde endosulfan I endosulfan II endosulfan sulfate aldrin dieldrin chlordane methoxychlor toxaphene

Table 3-2 (Continued)

Contaminant Type	Compound Class	Representative Compounds	
	Polychlorinated biphenyls (PCBs)	Arochlor 1016	Arochlor 1248
		Arochlor 1221	Arochlor 1254
		Arochlor 1232	Arochlor 1260
		Arochlor 1242	
Non-volatiles	Inorganic metals and nonmetals	aluminum	lead
		antimony	magnesium
		arsenic	manganese
		asbestos	nickel
		barium	potassium
		beryllium	selenium
		cadmium	silver
		calcium	sodium
		chromium	thallium
		cobalt	tin
		copper	vanadium
		iron	zinc

Table 3-3
Example of Typical Concentrations of HAPs in the Atmosphere

Category	Concentration range
PAHs	10-100 ng/m^3
PCBs	1-10 pg/m^3
Pesticides	10-100 ng/m^3
Particles	10-50 g/m^3
Volatiles	0.5-5.0 ppb

- Variety of types of air contaminants (organic, inorganic, biohazard, radioactive).
- Physical state of air contaminants (gas, liquid, solid).
- Level of air contaminant emissions.
- Air monitoring objectives.
- Potential availability of standard sampling and analytical techniques.
- Homogeneity of the waste material.
- Potential analytical interferences from the site.

The rate at which soil contaminants are emitted to the air depends in part on their volatilities (for gaseous contaminants only), which in turn depend on vapor pressures and Henry's Law constants. Highly volatile compounds will typically be emitted at a higher rate than compounds of similar concentration in the soil but lower volatility. Computer models that rely in part on compound vapor pressure and Henry's Law data as input are often used to estimate potential emissions to the air. Emission rates can then be used as input to an atmospheric dispersion model to gauge both short-term (e.g., 1-year) concentration levels at the facility fenceline and off-site receptors. Semi-volatile and nonvolatile compounds may also be of concern when they exist in significant concentrations and there is the potential for the dispersion of wind-blown dust.

It often is not practical to monitor for every compound present in the soil or ambient air because of the limitations of available technical or financial resources. In these cases, potential target compounds should be ranked in terms of predicted concentration levels and applicable health-based action levels. Note that the potential adverse health effects vary from compound to compound, and the health-based action levels may vary by orders of magnitude between compounds with relatively similar structures and physical properties. For example, 1,2-dichloroethane is considered to be a much more potent carcinogen than 1,1-dichloroethane, and benzene is considered to pose a much more significant risk than equal amounts of toluene or xylene. Therefore, the most significant compounds at the site from a health risk standpoint might not necessarily be those present in higher concentrations in the soil or water.

Table 3-4
Relationship Between Ambient Air Monitoring Design Elements and the Three Phases of Remediation at a HTRW Site

	Three Phases in the Remediation of a HTRW Site		
	Phase I:	Phase II:	Phase III:
Design element	Pre-remediation or baseline study	Remediation study	Post-remediation study
Number of target compounds	Multiple compound classes; full analyte list	1-20	<10
Data quality objectives	Identify compounds accurately; semi-quantitatively	Quantify level of specified compound(s)	Quantify level of specified compound(s)
Sampling			
Period	24-hour	8-24 hours	24-hour
Duration	5 days to 1 year	Duration of remediation	5 days to 1 year
Frequency	Daily to once every 6 days	Daily	Daily to quarterly
Number of sampling locations	4-12	4-12	4-12
Monitoring method characteristics	Low detection limits Applicable to broad range of compounds	Rapid data turnaround Low detection limits Specific target compound list	Low detection limits Specific target compound list

Basically, the objective is to find the type and/or species that could be used to assess air quality impacts from the site during investigation and/or remediation activities. The ideal target compound should be:

- Found in air emissions from the site in a fixed ratio to other constituents.
- Non-reactive or stable species.
- Found at levels above analytical detection limits.
- Unique to the site.
- Known toxicity and acceptable exposure criteria.

Consequently, the objective of developing a site specific TCL is to provide a prioritized list of compounds for which an FFMS can be developed. The TCL should be comprised of those compounds that are most commonly found at the site, pose the most significant threat to human health, and that are likely to enter the air pathway. The number of target compounds to be monitored vary depending upon which phase the HTRW site remediation program is occurring, as identified in Table 3-4,

(3) Ranking of target compounds utilizing a basic algorithm. To assist personnel in developing a TCL, the EPA has developed a simple algorithm to rank compounds at HTRW sites in order of importance. Considerations in developing the ranking scheme were health effects, regulatory needs, potential for human exposure through the air pathway, and use of available data bases.

Table 3-5
Example of Components of the RIA Program for a HTRW Site

Rank	Descriptor
1	Health effects index
2	Analyte identified at the site and on the Hazardous Substance Priority List (HSPL)
3	Regulated by State agency
4	Listed in California Air Resource Board (CARB) List of Lists
5	Listed in New York Air Guide One
6	Frequency of occurrence at NPL sites
7	Volatility index (VI)
8	Listing in SARA Title III
9	Availability of analytical methodology
10	Availability of reference standard

The ranking index algorithm (RIA) is comprised of 10 components, as listed in Table 3-5 in order of their ranking. Following is a brief discussion of each of the components of the algorithm.

(a) Health effects index. In considering health effects, available data developed by EPA's Pollutant Assessment Branch (PAB) and generally contained in the list of unit risk factors for the inhalation of carcinogenic air contaminants should be used. This list is maintained by PAB for air assessments performed within EPA's Office of Air Quality Planning and Standards (OAQPS). The PAB also maintains a separate list of compound "cancer potency slopes" that, in most cases, are based upon ingestion routes of exposure. Because in many cases these cancer potency slopes have been, and will continue to be, converted to inhalation factors for use in air toxics risk assessments, data could be included in the health effects index ranking.

For those compounds that are non-carcinogens, EPA has determined a RfD value. The RfD's are used by EPA as threshold values in evaluating non-carcinogenic health effects. For other compounds on the list not described by any of these data bases, one can rely on various health effect indicators such as threshold limit values. As a last resort, consult reportable quantity data from SARA Title III listing.

(b) Regulated by State agency. The National Air Toxics Information Clearinghouse should be used as an indicator of state regulatory activity for specific HAPs. For the various states regulating on the basis of reference ambient levels (RALs), frequency of occurrence of regulations for specific chemicals should also be an important ranking criteria.

(c) Regulatory list. Frequency of occurrence on lists of hazardous materials should also be considered as a useful ranking indicator. The California Air Resources Board (CARB) publishes a "List of Lists" that shows the frequency with which specific chemicals are listed in 12 authoritative lists of hazardous chemicals. The New York Air Guide II also categorizes specific air toxics compounds at high, medium, or low toxicity. SARA Title III, Section 313 also lists hazardous pollutants. Frequency of occurrence in each of these lists should be used as an indicator of relative importance of these compounds, occupying the 2nd, 4th, 5th, and 8th positions in order of importance of ranking criteria.

(d) Potential for human exposure through air pathways. Indicators for the potential for human exposure should be incorporated by considering both the frequency of occurrence at the HTRW site and the volatility of each of the listed compounds. Frequency of occurrence at different sites can be obtained directly from the EPA list entitled "Frequency Distribution of Substances Present at Final and Proposed NPL Sites." A volatility ranking number between 0.5 to 3 for each compound should be derived from boiling point and/or vapor pressure data, as available. These indicators are generally considered to represent potential for human exposure though the air pathway at the site and was assigned the 7th position in the ranking scheme.

(e) Availability of analytical methods and reference standards. The 9th and 10th weighing positions were assigned to availability of analytical method and reference standard, respectively. For marginal compounds, the availability or lack of analytical methods and reference standards should be a factor in the decision to include or exclude such compounds from the TCL.

In summary, the following considerations should be used to develop the site-specific TCL:

- Frequency with which compounds have been found at the sites.
- Compounds that present a risk of exposure by inhalation and that are highly toxic or carcinogenic.
- Frequency with which compounds are requested under Federal or State regulations (ARARs and TBCs) to meet cleanup goals.

- Availability of sampling/analysis methods and reference standards for the target compounds.

- Relative volatility of the candidate compounds.

- Availability of health-based data (unit risk, reference doses and acceptable ambient levels) for the target compounds.

To complete the ranking process, each of the candidate analytes should be entered into a spreadsheet and arrayed with corresponding numerical data describing each of the 10 ranking criteria. A RIA is then devised that positions the maximum value of each of the ranking criteria terms in its relative weight positions. The algorithm, the ranges of the numerical data in the spreadsheet, and the relative maximum term values are shown in the following equation:

$$RIA = 10G + 11.3B + 120M + 7.5D + 23.3F + 10K + 20L + 40E + 35C + 15J$$

where:

G = health effects;
B = analyte identified at a site or on Hazardous Substance Priority List (HSPL);
M = analyte regulated by state or Federal agency;
D = listed into CARB list;
F = listed into Air Guide II list;
K = frequency of occurrence at NPL sites;
L = volatility index;
E = listing in SARA Title III;
C = availability of analytical methods; and
J = availability of reference standards.

Health effects, for example, should be designated as the most important of the descriptive criteria and accordingly ranked number 1; availability of a reference standard should be the least important, ranked number 10.

For convenience in developing a RIA ranks are assigned corresponding maximum values of the algorithm terms representing the descriptors. For health effects, a maximum term value of 100 should be selected, while for availability of reference standard, a maximum term value of 30 should be selected. Intermediate term values for other descriptors should be selected so that each algorithm term representing a descriptor that can be retained in the relative position.

For health effects, each chemical should be assigned an index value between 1 and 10, with 10 being the maximum value of the health effect descriptor and representing the greatest level of health hazard. For availability of reference standard, each chemical should be assigned an index value between 0 and 2, with 0 representing no standard available and 2 representing availability of EPA-certified standard. The algorithm constant is derived by dividing the maximum term value by the maximum numerical index value arrayed in the spreadsheet. For health effects, the algorithm constant was 10 (100/10), while for the availability of reference standard, the algorithm constant was 15 (30/2).

Table 3-6
Example Of RIA And Deviation Of Term Values
RIA = 10G + 11.3B + 120M + 7.5D + 23.3F + 10K + 20L + 40E + 35C + 15J

Data source			Computer spreadsheet range of numerical data			Derived constant for algorithm (a ÷ b)
Descriptor	**Rank[a]**	**Selected max. value of descriptor[a]**	**Algorithm variable**	**Minimum value**	**Maximum valuable[b]**	
• Health effects index	1	100	G	1	10	10
• Analyte identified at site and on Hazardous Substances Priority List (HSPL)	2	90	B	0	8	11.3
• Regulated by State agency	3	80	M	0	0.667	120
• Listed in CARB list of lists	4	75	D	0	10	7.5
• Listed in New York Air Guide II	5	70	F	0	3	23.3
• Frequency of occurrence at NPL sites	6	65	K	0	6.5	10
Volatility index	7	60	L	0.5	3	20
Listing in SARA Title III	8	40	E	0	1	40
Availability of analytical method	9	35	C	0	1	35
Availability of reference standard	10	30	J	0	2	15
Maximum value of algorithm		645				

[a]Relative importance of descriptor.
[b]Numerical data expressed as decimal fraction.
[c]Numerical data expressed a decimal fraction x 100, for multiple listings only.

Utilizing the RIA for a series of EPA Superfund sites nationwide, the first twenty (20) ranked compounds are calculated as:

Rank	Compound	Rank	Compound
1	Vinyl chloride	4	Chloroform

2	Trichloroethylene	5	Benzene
3	Cadmium	6	Carbon Tetrachloride
7	Arsenic	14	Heptachlor/Heptachlor epoxide
8	Tetrachloroethylene	15	1,2-dichloroetheneFormaldehyde
9	Chromium	16	Acrylonitrile
10	Mercury	17	Benzo(a) pyrene
11	Beryllium	18	1,2-Dichloroethane
12	Selenium	19	Chlorobenzene
13	Nickle	20	Lead

The ranking index should be designated as the sum of the descriptor terms with a maximum value of 645, as illustrated in Table 3-6.

Table 3-7 illustrates a sample calculation for ranking vinyl chloride. The complete target compound list developed for EPA nationwide for Superfund sites consists of approximately 257 target compounds. Of the 257 compounds, 43% are volatiles having vapor pressure greater than 0.1 mm Hg. Approximately 32.4% of the target compound list are classified as semi-volatiles with vapor pressure ranging from 10^{-1} to 10^{-7} mm Hg. Finally, inorganic metals comprise approximately 28% of the target compound list. Appendix G contains the full target compound list of 257 compounds as developed for EPA to be used at Superfund sites utilizing the algorithm.

Table 3-7
Example of Sample Calculation For Vinyl Chloride

Value of variable in algorithm[a]	Descriptor	Vinyl chloride term value[b]
G = 4	Health effects index	40
B = 8	Analyte identified at site and on HSPL	90
M = 0.5	Regulated by State agency	60
D =10	Entered in CARB list of lists	75
F = 3	NY Air Guide List	70
K = 1.51	Frequency of occurrence at NPL sites	15
L = 3	Volatility index	60
E = 1	Listing in SARA Title III	40
C = 1	Availability of analytical method	35
J = 2	Availability of reference standard	30
	Total algorithm value for vinyl chloride	515

RIA = 10G + 11.3B + 120M + 7.5D + 23.3F + 10K + 20L + 40E + 35C + 15J
= 10(4) | 11.3(8) + 120(0.5) + 7.5(10) + 23.3(3) + 10(1.51) + 20(3) + 40(1) + 35(1) + 15(2)
= 40 + 90 + 60 + 75 + 69.9 + 70 + 15 + 60 + 40 + 35 + 30
= 515

[a]Values for vinyl chloride terms from spreadsheet.
[b]Rounded off to nearest whole number.

(4) Summary. The process of developing a site specific TCL from a general universe of compounds is critical in meeting the project's objectives. The overall objective of the site specific TCL is to identify species that are common to the waste, likely to be present in emissions and can be sampled and analyzed by the FFMS. The target compound list should be composed of compounds that are:

- Found uniformly in the waste and at a relatively constant ratio to other contaminants.
- Relatively non-reactive and stable in ambient air.
- Found in the downwind plume well above the analytical detection limit of the sample collection/analytical technique.
- Unique to the site and not found in the upwind air at significant levels.

Representativeness of these compounds should be demonstrated at the onset of the program and perhaps throughout the program. This verification of target compounds is critical for demonstrating the applicability to the FFMS at the site. Figure 3-8 summarizes the steps one should perform in developing a site specific target compound list using the RIA system.

3-6. Technical Consideration in the Development of a Fixed-Fenceline Sample Collection and Monitoring System.

a. Introduction. To achieve the objectives of a real-time FFMS, proper planning and organization are required that attain the data collection goals, minimizes cost and ensures that the data is defensible and is of known and acceptable quality to meet the needs of the primary data user (decision maker). An effective way to accomplished these objectives is to implement EPA's DQO process as outlined in Paragraph 3.2. This process applies to all HTRW remediation projects where monitoring data is to be used to make project decisions. DQOs are qualitative and quantitative statements produced when implementing the program.

The overall goal of an APA is to estimate the site's actual or potential effects of emissions to the surrounding air quality. A major objective of the APA is to estimate the pollutant levels from the site at the fenceline and their transport to the off-site community and environment. The evaluation of off-site exposure generally requires that monitoring be performed whenever significant air emissions may be released from the site. At sites that have the potential for adversely affecting the air, this requirement is often addressed by establishing a fixed network of sample points around the perimeter of the site where samples are extracted on a continuous basis. Collecting samples on a continuous basis allows for an evaluation of the effectiveness of the hazardous pollutant control options installed at the HTRW site during remediation activities, and allows for immediate corrective action based upon real-time pollutant concentration data coupled with on-site meteorological data. It is therefore imperative that specific technical considerations be given when implementing a real-time, volatile FFMS because the output of this system will be used for both health and safety considerations at the site and for documenting the achievement of complying with regulatory emission limits.

To achieve the above objectives, a number of crucial areas need to be considered in the design and implementation of a real-time volatile FFMS. They are:

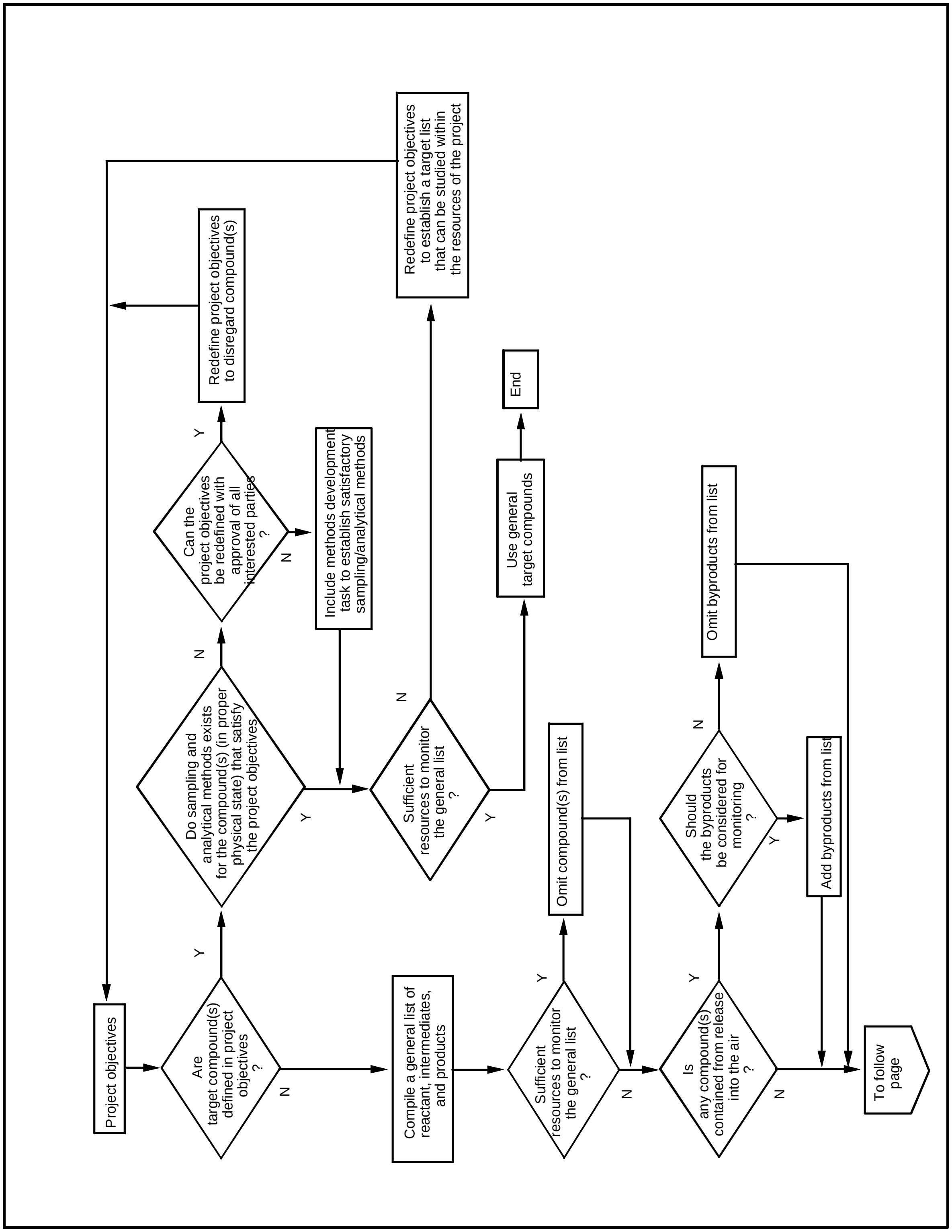


Figure 3-8. Example of flowchart for defining a site specific target compound list at a HTRW site.

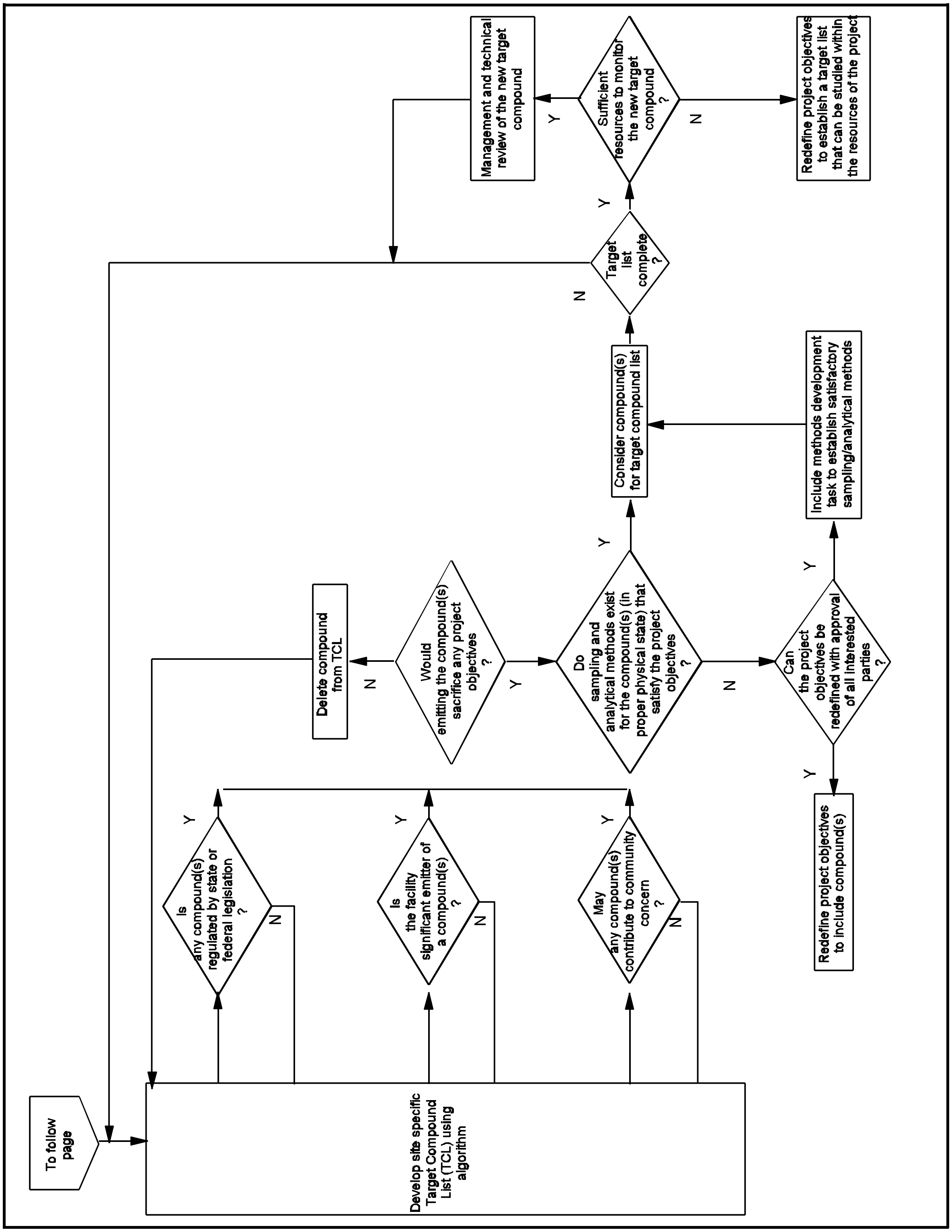


Figure 3-8. (continued)

- The selection of toxic compounds for analysis, based on toxicity and the likelihood of human exposure.
- The applicability of sampling techniques to specific target compounds or classes of compounds.
- The design and implementation of the FFMS.
- Long term performance of the analytical system to meet project DQOs.
- Site characteristics associated with the location of inlet probes and analytical center.

b. Designing monitoring strategy. The first step in designing a monitoring strategy is to determine the overall objectives of the sampling program. Most problems in sampling program design can be traced directly to misunderstandings about overall sampling objectives. The importance of a well thought-out set of sampling program objectives cannot be overstated.

In developing a monitoring strategy to meet sampling program objectives, several crucial items should be provided. These include:

- Processes and/or sources to be characterized.

- Any relevant rules that require the monitoring program to be conducted, and any specific Agency requirements.

- The intended use of the monitoring data.

- A summary of DQOs and other QA concerns.

- Any cost, physical, and time constraints.

The purpose for specifying the above items up-front is to allow plan preparers to clearly understand the technical requirements of the sampling program and to allow plan reviewers to critically evaluate the technical specifications of the plan and the data that the program will generate.

The development of a monitoring strategy also forces interested parties to "think through" the purposes of the program and to reach a consensus on critical requirements before the commitment of funds. An example of sampling program objectives for an HTRW site assessment study is presented in Figure 3-9.

c. Acceptance air risk specific concentration. One of the primary purposes for conducting a real-time FFMS program is to provide the data required for an inhalation risk assessment for both on-site and off-site receptors. The concept of the "acceptable air risk specific concentration" (acceptance concentration) was developed by EPA to assist in the identification of methods capable of detecting airborne HAPs concentrations low enough to permit a meaningful risk assessment to be performed at various levels. The acceptable risk concentration specified by EPA is 10^{-6}, which means that to detect HAPs at an inhalation risk of 1-in-1 million (10^{-6}) level, the selected sampling method must be capable of quantifying concentrations at least as low as the acceptance risk concentration. (In other words, the acceptance concentration equals a maximum individual risk of 10^{-6}.) The EPA's Superfund Public Health Evaluation Manual defines an acceptable level of cancer risk as being in the range of 10^{-7} to 10^{-4}. (This range represents the acceptable level of risk for an adult exposed to maximum predicted ambient air concentration for a 70-year period, 24 hours per day. A 10^{-7} risk is a 1-in-

10 million chance of death from cancer, whereas a 10^{-4} risk is a 1-in-10 thousand chance of death from cancer.) Obviously, air sampling methods must be capable of measuring ambient contaminant concentrations corresponding to risks within the 10^{-7} to 10^{-4} range.

As an example of how acceptance concentrations can be used in selecting sampling methods, consider the compound vinyl chloride, whose acceptance concentration is 0.024 µg/m^3. A vinyl chloride concentration in ambient air of 0.024 µg/m^3 represents an inhalation-based cancer risk of 10^{-6} (i.e., for every 1 million adults who are exposed to this concentration over 70 years, one adult would be expected to die from cancer related to vinyl chloride exposure). If vinyl chloride is present in the ambient air at a concentration of 0.024 µg/m^3, and if the air sampling system used to measure vinyl chloride concentrations is not designed such that concentrations as low as 0.024 µg/m^3 can be detected, then the risk of cancer would not be detected. (Instead, the analytical results would be reported as "below detection limit.") Obviously, if the characterization of risk levels as low as 10^{-6} is a DQO of the sampling program, the sampling method must be capable of detecting concentrations as low as the acceptance risk concentration. (The same argument also holds for acceptance concentrations based on other risk levels of interest.)

Derivation of the acceptance concentrations is straight-forward and can be performed at any risk level of interest and for any compound having an inhalation unit risk factor for cancer. The derivation formula is as follows:

$$\text{Ambient Air Level (AAL)} = \frac{\text{Risk level of interest}}{\text{EPA's unit risk factor}}$$

where:

Risk level of interest = The lowest level of inhalation risk at which site investigators wish to characterize the risk of death from cancer for an adult exposed to ambient air concentrations of the contaminant of interest, for a 70-year period, 24 hours per day (i.e., 10^{-4}, 10^{-5}, 10^{-6}, etc).

EPA's unit risk factor = A common measure of a compound's carcinogenic potency via the inhalation route of exposure, in units of m^3/µg. Appendix G contains many unit risk numbers for several hazardous air pollutants. The unit risk factor times the ambient air concentration of the compound equals the risk of cancer for an exposed individual.

Again using vinyl chloride as an example, the acceptable AAL concentration at a 10^{-6} risk level is calculated as follows:

$$\text{AAL for vinyl chloride} = \frac{10^{-6}}{4.2 \times 10^{-5}}$$

$$= 0.024 \ \mu g/m^3$$

SAMPLING PROGRAM OBJECTIVES

The objective of this FFMS program is to assess compliance with Rule XXX by measuring HAPs emissions from the HTRW site. The Rule provides a list of toxic compounds which must be assessed (see Table X), and specifies concentrations that will be monitored as 24-hour average concentrations. The intended use of the data will be to perform an HAPs risk assessment for both nearby residents and on-site workers at the one-in-a-million (i.e., 10^{-6}) risk level. Both carcinogenic and non-carcinogenic, acute health effects are to be assessed.

USACE has determined that the following data quality objectives are necessary to assure that the sampling results are meaningful:

Accuracy:	±30%
Precision:	±30%
Completeness:	At least 80% of validated data must be acquired. The expected failure rates of the selected sampling methods should be considered in determining the number of separate measurements to plan for.
Representativeness:	Emission measurements should reflect normal conditions at the site over a 24-hour period. The data will be used to calculate emission rates.
Comparability:	The selected methods and procedures should be similar to those recently used at the USACE site so that emissions from the two sites can be compared.

All measurements and analyses must be completed by the end of physical year 19XX. Due to site access problems during the rainy season, it is preferred that all measurements be made during the summer months, provided that this can be accomplished without seriously sacrificing the representativeness of the sampling program. Costs should be minimized through the use of screening techniques wherever possible.

Figure 3-9. An example of sampling program objectives for a HTRW site assessment study

The risk level of 10^{-6} has been chosen as the basis for AALs concentration values presented in Appendix G because this is the level of risk most often monitored by EPA's Regional Offices. Similar calculations can be performed at other risk levels of interest.

Unfortunately, for some of the more hazardous air pollutants, it will not be possible to design a practical real-time volatile FFMS that is capable of detecting the very low ambient air concentrations corresponding to a 10^{-6} risk. In these situations, it will be necessary to modify the objectives of the risk quatification as defined in the DQOs of the USACE sampling program. For example, it may be necessary to be satisfied with a risk quantification goal of 10^{-5} or even 10^{-4}, which would raise the detection limit of the real-time volatile FFMS to a detectable level. Alternatively, if a number of hazardous compounds are present in the ambient air, it may be possible to use an easily-measured compound as an "indicator" of a more difficult-to-measure compound. Another alternative would be to calculate risk for the compound using the worst-case assumption that concentrations are present at the lower limit of detection for the real-time volatile FFMS.

When applying the AAL concept, it is important to allow for the presence of multiple carcinogenic compounds. Inhalation risks are usually assumed to be additive. Thus, if an objective of a USACE HTRW program is to quantify inhalation risk at levels as low as, say, 10^{-6}, and if more than one carcinogenic air contaminant is present, then the *sum* of risks for the individual compounds must be determined. Although the sum of risks may exceed 10^{-6}, the contribution to total risk by each of the individual compounds may be less than 10^{-6}. The sampling method must be capable of detecting concentrations associated with these low risk values (i.e., less than 10^{-6}), thereby making detection at levels *below* the AAL concentrations outlined in Appendix G desirable.

d. Site characteristics. One of the most important aspects to consider when evaluating site characteristics is the site terrain. The geometry of the site and the contour of the location directly influence the extent and the design of the FFMS program. Extremely complex terrain will complicate the migration of contaminants and make evaluation techniques complex with uncertain results. Fixed-point monitors may not be as effective as the application of open-path optical remote sensing devices because of the likelihood of the fixed-point monitors missing the "site plume." To compensate, one can increase the number of fixed-point monitors as part of the FFMS program on both the horizontal and vertical plane in an attempt to characterize the site plume. Another option is to use air dispersion modeling to map the site plume; however, air dispersion modeling is often difficult to implement and results are often inaccurate and non-representative.

Local meteorological conditions will also play a major role in the design of a perimeter air monitoring program. The placement of inlet extractive probes or time-integrated monitoring systems must be such that the gas sample analyzed is truly representative of the site emissions regardless of wind direction. Historically, the evaluation of the 5-year wind rose is used to help locate inlet probes in an upwind/downwind scenario based upon the dominant wind direction. However, the uncertainty of the meteorological conditions at the site would require, at a minimum, four inlet probes around the site with the first inlet probe placed in the upwind quadrant based on the 5-year wind rose and the remaining probes at 90 around the site. This placement allows for appropriate coverage at a reasonable cost. Paragraph 5-3 discusses in greater detail the placement of inlet probes in association with site specific meteorological conditions.

Accessibility to sampling sites and inlet probes is also a consideration when designing the perimeter air monitoring system. Under best conditions, the site will have an access road around the perimeter where the inlet probes are located for ease of maintenance and auditing functions. The access road saves time and labor when performing probe tip audits because equipment can be transported to the site by vehicle over rough terrain rather than hand-carrying to the location. Finally, a perimeter air monitoring station should be located outside the exclusion zone to minimize the personal protection equipment (PPE) requirements as part of the site health and safety program. If the sites are located in the exclusion zone, then a level A or B may be required. Working under these levels of protection is extremely difficult, requiring considerably more time and expense to complete a simple task. Again, depending on the project, road accessibility and locating the inlet probes outside the exclusion zone may be important to the successful completion of the project within a defined timeframe and restricted budget.

Available utilities are not as important for an FFMS program as they would be for a time-integrated network of samplers. As part of the heat-trace line component of the extractive system (see Paragraph 5-4), all electrical needs are self-contained in the umbilical cord. Consequently, the probe inlet, filter, and lines are heated to operating temperatures by electrical connections extending from the analytical center to the probes via the umbilical cord. However, if the program requires collocated volatile samples or other time-integrated systems (i.e., PM-10/TSP samplers, semi-volatile samplers, etc.) at the probe perimeter locations, it may be wise to establish line power to operate these systems rather than using portable generators or battery powered instruments. This requirement is especially essential if the perimeter air monitoring program is to be operated over several years rather than months. If the program is short in duration and the air pathway can be monitored using simple, battery-powered instrumentation, line power is not needed.

e. Evaluation of available information. A substantial savings in sampling time and costs can be realized by evaluating existing information. While such information seldom satisfies the objectives of the sampling program, the information can provide valuable insight into what analytes to sample, when and where sampling should be performed, and what sampling techniques are likely to be successful. For example, data from a past sampling program at a similar site may indicate which compounds are likely to be present and at what concentrations. Historical data from a nearby site might indicate the extent to which background concentrations may contribute to the on-site concentration measurements. Additionally, information may be available on contaminant phase distribution characteristics and monitoring equipment performance. The time devoted to locating and reviewing information on past test programs usually pays for itself in the development of a more efficient sampling strategy. Appendix D, Hazardous Air Pollutants Data Bases, provides guidance on proper methodology selection for over 1,000 HAPs detected at hazardous waste sites.

f. Meteorological data. Ordinarily, the monitoring strategy will include the collection of meteorological data. An important reason for evaluating these data is to determine whether the atmospheric condition and pollutant concentration have an impact on the surrounding community and are truly “representative” of conditions at the site. For example, because the volatilization of toxic compounds from contaminated soil is influenced by soil temperature and moisture, temperature and rainfall measurements may be especially important to monitoring strategies where the volatilization of contaminants from the soil is to be characterized. In this example, an effort would be made to conduct the monitoring program during periods when temperatures and rainfall are within normal ranges for the locale under study. At a minimum, the following meteorological parameters should be monitored on a continuous basis:

- Wind speed and direction.
- Temperature (10-meter and 2-meter).
- Relative humidity.
- Barometric pressure.
- Precipitation.
- Solar radiation.

Meteorological data are also important in determining where to site inlet probes and monitoring equipment, and in assuring that siting decisions remain appropriate throughout the test period. The usual strategy for siting inlet probes is to establish monitoring locations downwind of the source, with possibly one or two locations upwind of the source for background measurements. The use of an on-site specific meteorological station both before and during the sampling period will provide the information necessary to make intelligent decisions about monitor siting. Chapter 6 discusses in greater detail the meteorological system and its role in a real-time, fixed-fenceline real-time FFMS program.

g. Selection of instrumentation and analytical methods. An obvious factor in the selection of instrumentation and analytical sampling methods is the ability of the method to measure the compound of interest at a specified concentration, typically in the low ppbv range for highly toxic compounds. The ability of a sampling method to measure low concentrations will depend on several factors, including:

- The sensitivity of the sampling method for the particular compound of interest.
- Applicability of the method to monitor all target analytes.
- Ability of the instrumentation to collect, speciate and detect specific analytes.
- Cost constraints.
- Instrumentation performance and reliability.
- The detection limit of the chosen instrumentation and analytical method.
- Ease of set-up and operation.

Other important factors to consider in the selection of sampling methods are (1) the potential for artifact formation, (2) the minimization of erroneous data due to interfering compounds, (3) the ability of the method to achieve desired data quality objectives, (4) the ability to simultaneously measure other compounds of interest, and (5) the compatibility of the sampling method with available analytical methods. Questions that should be answered in the selection of instrumentation are:

- Can the selected instrument detect the probable target compounds?
- Does the sampling methodology sample the analyte effectively and quantitatively?
- Does the instrument transfer the analyte quantitatively from the inlet to the analytical detector?
- Can the instrumentation produce precise, accurate, and quantitative results for all of the analytes listed in the monitoring program goals?
- Does the selected instrumentation have detection limits low enough to meet the overall objectives of the sampling program?
- Would the methodology be hampered by any interfering compounds?

h. Selection of compounds for measurement. Compounds should be selected for measurement based upon the program objectives and evaluation through the APA program. For example, if the perimeter air monitoring program is intended to assess compliance with Federal, state or local rules or policies, these rules or policies may specify the compounds for which measurements are required. Additional factors to be considered in selecting compounds for measurement include:

- Expected presence in the atmosphere based on the presence of soil or groundwater analyses or on historical material usage records.
- The potential for adverse health effects by the inhalation route of exposure.
- The technical feasibility of the monitoring and measurement systems.
- The likelihood that atmospheric degradation or formation processes may alter compounds concentrations in the atmosphere.
- Sampling cost considerations.
- Regulatory requirements.

As illustrated in Table 3-8, the selection process should also consider ranking of the compounds (see Paragraph 3-5), depending on whether they are regulated, whether dependent on percentage of positive hits in the soil, whether the compounds were detected in the air during background monitoring, or whether they were detected during bore hole testing. Once the larger list of compounds is identified, then that list needs to be reduced to a more manageable number (less than 5) of compounds that can be monitored by a real-time GC system. As an example, Table 3-9 identifies the three target volatile organic compounds that were selected from a larger list of compounds (Table 3-8) for real-time monitoring at an HTRW site.These compounds were selected because they represent an aromatic, an alkene, and a chlorinated aromatic. Table 3-9 also identifies the OSHA PELs, PALs and the AAL (at 10^{-6} risk level) for the three selected analytes. Using Table 3-9, one can determine that an on-site GC system can detect the target analytes at 10^{-6} risk levels or if another risk level needs to be evaluated as part of the DQO process.

In situations where the available sampling methods are not capable of measuring an analyte at concentrations as low as desired (as often occurs with some of the more toxic compounds), it may be reasonable to measure a surrogate compound instead. This surrogate would be a compound that ordinarily co-exists in the atmosphere with the compound of concern, but is more easily measured. Thus, the presence of the surrogate compound would"indicate" the presence of the compound of interest.

Table 3-8
Example of Compilation Of Analytes Of Interest As Part Of The Selection Process at a HTRW Site

Ranking	Analyte	Boiling Point (C)	OSHA PELS (ppm)	State regulated	% positive soil samples	Detected in background monitoring	Detected in bore hole monitoring
1	Acetone	56	--		48		
2	Benzene	80	10	**M**	2	**M**	**M**
3	Toluene	111	50		21	**M**	**M**
4	Xylenes	144	100		26	**M**	**M**
5	Methylene chloride	40	--		12	**M**	**M**
6	Trichloroethylene	87	50		20	**M**	**M**
7	Chloroform	132	--	**M**	4		
8	Chlorobenzene	132	10	**M**	60	**M**	**M**
9	Dichlorobenzene	174	25		20		
10	Tetrachloroethylene	121	25	**M**	20	**M**	**M**

Table 3-9
Example of Three (3) Site Specific Target Compounds Selected from Table 3-8 as Results From the Selection Process

Compound	On-site GC instrument quantitation limit, ppb	Instrument calibration range, ppb		OSHA PEL, ppb	Perimeter action level (PAL), ppb	Acceptable ambient level (AAL) at 10^{-6} risk, ppb
		Minimum	Maximum			
Toluene	0.2	0.5	2,000	91,463	914	1.9
Chlorobenzene	0.2	0.5	2,000	77,777	777	1.6
Tetrachloroethylene	0.2	0.5	2,000	25,110	251	0.9

Another consideration concerns the data quality likely to be associated with a particular measurement approach. For example, if measurements are made at concentrations close to the limit of detection for a given compound, the accuracy and precision associated with these measurements may be unacceptably poor and may not meet the program DQOs. In these situations, it may not be worthwhile to proceed with that measurement method.

A final scenario would be to monitor NMOC at a PAL of 1 ppm. Then, if exceeded, require the GC system to speciate the NMOC peak at detection limits below the 10^{-6} AAL value, as illustrated in Figure 3-10. This requirement would allow maximum flexibility for an on-line GC system design by allowing alarm levels at 1 ppm and risk levels (10^{-6}) determined at ppb levels, thus meeting USACE program DQOs.

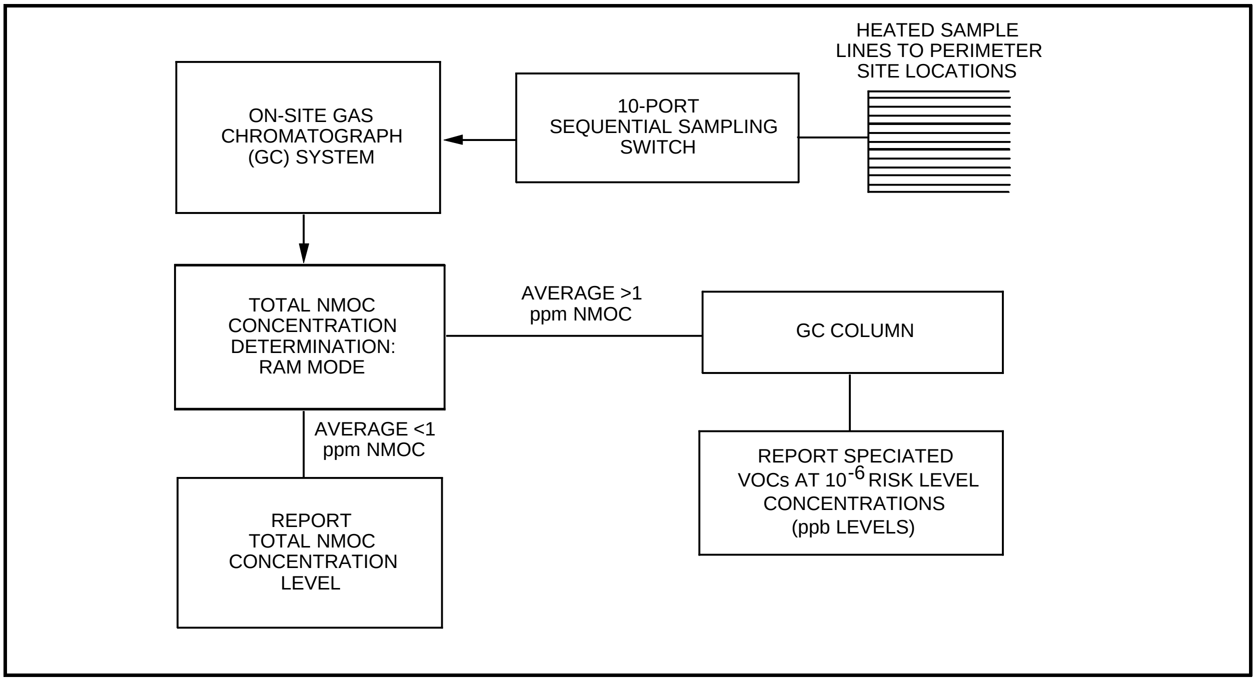


Figure 3-10. Example of application of monitoring NMOC/speciated organics at the site perimeter as part of the selection process.

i. Number and location of sampling sites. A variety of factors influence the number and location of probe inlets around a hazardous waste site. Factors that influence the required number and location of inlets at the site are:

- Evaluation of 5-year wind-rose for predominant wind direction.
- Location of potential on-site emission sources (i.e., process emissions, waste handling facilities, etc.).

- Location of topographic features that affect the dispersion and transport of site emissions.
- Location of sensitive receptors at the site perimeter and off-site.
- Location of off-site sources that might contribute as background contributors to on-site concentrations.
- The level of confidences needed to ensure that the maximum concentration levels are obtained.

In determining the number and location of sampling sites, dispersion models (screening and refined) should be used to assist in calculating ground-level concentrations in the site vicinity and to determine locations of maximum calculated concentrations for short-term (up to 24 hours) averages and long-term (monthly, seasonal, and annual) averages. Inputs into the dispersion model should include stack height for the treatment system, hazardous waste constituent concentration, previous 1-year on-site meteorological data, population close to the site, and sensitive population. The model outputs should be plotted as isolpeths of concentration. This information will assist in siting of monitoring stations. The first priority, however, should be to locate inlets that:

- Provide information on possible high impact of emission plume on sensitive receptors (i.e., concerned citizen, downwind communities, schools, hospitals, etc.).
- Are positioned in the plume of expected high concentrations of source constituents based upon historical meteorological data and dispersion model results.

Typically, programs designed for determining long-term concentration levels (e.g., annual or lifetime exposures) will require fewer probe inlet locations than those intended to monitor compliance with short-term action levels. The long-term prevailing wind directions are usually more predictable than day-to-day wind patterns, and inlet sites, therefore, can be more accurately situated for measuring significant long-term effects.

For determining concentration levels with respect to short-term effects, a fixed network of sample inlets ideally should be located around the perimeter of the HTRW site, with additional samplers located near working areas and near sensitive receptors. The number of sampling sites will depend, in part, on the size of the HTRW site. For large sites surrounded by nearby residences, a 12-station network would provide nearly complete spatial coverage at the fenceline (i.e., one sampling station every 15), as illustrated in Figure 3-11. However, cost considerations may not allow this

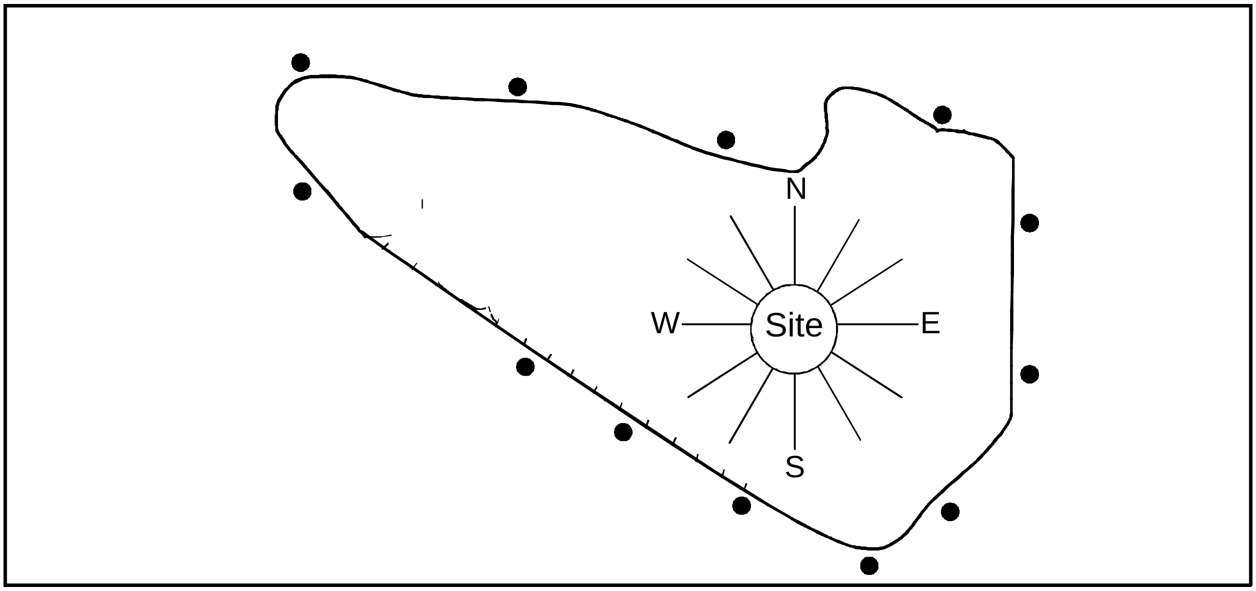


Figure 3-11. Example of a 12-point monitoring network HTRW site

arrangement. Another example would be to determine the predominant 5-year wind rose and place one inlet probe upwind and three inlet probes downwind. A better application of the four station arrangement would be to locate an inlet probe at the centroid of each of the 90 quadrants of a circle based upon the 5-year wind rose, as illustrated in Figure 3-12.

Each of the inlet probes serve specific objectives as part of the FFMS program:

- Inlet probe #1: Inlet probe #1 is the predominant upwind site based upon the previous 5-year wind rose. This inlet should identify specific constituents entering and impacting the site.

- Inlet probe #2: Inlet probe #2 is the second probe that provides data on the impact of emissions from the site.

- Inlet probe #3: Inlet probe #3 is the predominant downwind site based upon the previous 5-year wind rose. It should be located approximately 180 from inlet probe #1. Working with probe #1, a predominant upwind/downwind concentration of the emissions from the site can be instantaneously calculated.

- Inlet probe #4: Inlet probe #4 monitors the impact of emissions from the site.

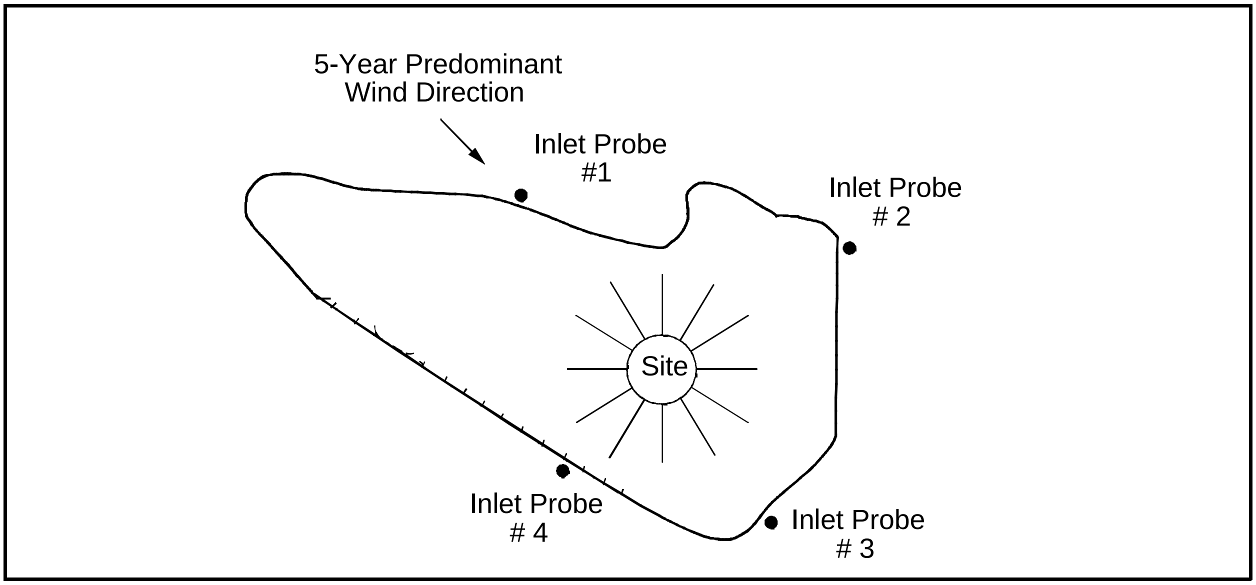


Figure 3-12. Example of a 4-point monitoring network with inlet probes at 90 location

After the number of stations have been determined, the placement of probes must be considered. In many cases, constraints on placing inlet probes can be encountered because of wind flow obstructions caused by nearby buildings, trees, hills, or other obstacles. Other constraints might be related to security, the accessibility of electrical power, as well as the proximity to roadways or other pollution sources that might affect the representativeness of the sample for measuring the waste site's effects on air quality. Specific guidelines for probe siting for sampling representative conditions are given in Table 3-10.

j. Cost factors. A number of issues affect the cost of establishing and conducting a FFMS at a HTRW site. Those issues are:

- Objectives of the perimeter air monitoring program.
- Analytes to be monitored and the program required detection limits.
- Frequency and duration of the monitoring program.
- Assessibility for installation of the perimeter system.
- Contingency monitoring.

Table 3-10
Example of Summary of Key Probe Siting Criteria for FFMS Program

Factor	Criteria
Vertical spacing above	• Representative of the ground breathing zone and avoiding effects of obstructions, obstacles, and HTRW on-site traffic. Height of probe intake above ground in general, 2-3 m above ground and 2-15 m above ground in the case of nearby roadways.
	• 1 m or more above the structure which supports the inlet probe.
Horizontal spacing from	• Minimum horizontal separation from trees acting as an obstruction must be >10 m from the dripline.
	• Optimum horizontal separation from trees should be >20 m from the dripline.
	• Distance from probe inlet to an obstacle such as a building must be at least twice the height the obstacle protrudes above the inlet probe.
	• If the inlet probe is located on a roof or other structures, there must be a minimum of 2 m separation from walls, parapets, penthouses, etc.
	• There must be a sufficient separation between the inlet probe and a furnace or incinerator flue. The separation distance depends on the height and the nature of the emissions involved.
Unrestricted airflow	• Unrestricted airflow must exist in an arc of at least 270 around the inlet probe, and the predominant wind direction for the monitoring period must be included in the 270 arc.
Spacing from roads	• A sufficient separation must exist between the inlet probe and nearby HTRW on-site roadways to avoid the effect of dust and vehicular emissions on the inlet.
	• Inlet probe should be placed at a distance of 5-25 m from the edge of the nearest HTRW on-site roadway depending on the vertical placement of the probe inlet which could be 2-15 m above ground.

The objectives of the FFMS program will most certainly be affected by costs. Whether the program is established to monitor PALs, evaluate/document off-site exposure for protection of the surrounding community, or monitor on-site workers as part of an industrial hygiene program, overall costs are affected. The primary objectives will dictate the type of sampling equipment and analytical requirements to meet the DQOs of the program. Even the level at which emissions are to be monitored will affect cost. For example, if the alert level at the perimeter is measured in terms of NMOC rather than speciated organics, then the analytical equipment is less complicated, thus less costly. If, however, the purpose is to monitor at the risk level of 1-in-1 million, the analytical system must be far more sensitive, thus increasing the cost of the FFMS program substantially.

The number of type of analytes to be monitored will also affect the cost of the program. If the requirements are to monitor on a real-time basis for a large group of speciated organics, the program cost will increase. A larger analytical system will be required to be installed to give a full "chromatogram" of the analytes to be monitored. On the other hand, if one is able to select an appropriate subset of the compounds to be monitored and limit their number to less than five, cost savings can be achieved.

The frequency of sample collection will have a significant cost effect on the FFMS program. While real-time, on-site automated monitoring helps reduce the cost by the fact that analysis is on-site, the implementation of concurrent quality assurance monitoring using time-integrated systems must be taken into account, which brings into issue data turnaround and laboratory responsiveness as a factor in the decision for the implementation of the time-integrated monitoring techniques. Moreover, one must consider capital equipment, maintenance, and operational costs.

The duration of the monitoring program may influence the selection and implementation of the real-time program. Consideration must be given in the application of GC to the field environment. One must consider the ruggedness of the system, its ability to operate 24 hours per day, and the ability to maintain the system. While there are numerous systems on the market, many are "portable" and used for screening purposes rather than for long term FFMS application.

Assessibility of the FFMS must be taken into consideration when projecting cost. If the analytical center is within the exclusion zone, it will be more difficult to perform daily functions due to the level of protection. Likewise, the installation of up to 1,000 feet per sampling point of heat-trace lines must be considered as part of the overall cost estimate of the system. These lines must be protected from on-site traffic during activities at the hazardous waste site, which may require burying the lines or encapsulating them for protection from on-site heavy vehicle traffic. In addition, long term maintenance of the heat-trace lines must be considered as part of the operating cost of the system.

Finally, contingency monitoring must be considered when implementing a real-time FFMS program. Many regulatory agencies require that the monitoring system be available for a certain percent of the time (i.e., 80%). To address system downtime, contingency monitoring must be implemented, which may require temporary manual sampling procedures or may require a separate system which has been certified similar to the primary system. Costs can be a major factor for determining the sampling contingencies.

For USACE projects, costs should be developed delineating labor, material, and equipment costs for each FFMS. Each component of the FFMS should be costed out separately, since each system and the applicable technologies selected during system design will be different for each project/designer. Vendor information, (including company, point of contact, and cost quote) should be provided with each cost element. Providing this level of detail will facilitate loading the cost information into USACE cost estimate databases. The costs should be structured using the HTRW Remedial Action Work Breakdown Structure (RAWBS) format shown in Figure 3-13.

The example cost estimates given in Table 3-11 are an expansion of Section 331XX.02.03.01 of the USACE HTRW RAWBS and are based on the assumption that all capital equipment is bought and not leased. In addition, costs are provided on a per-unit basis, both for equipment and analytical work as part of the QA program. Other expenses, such as labor requirements for network operation and data management and reporting, are given as estimated number of man-hours/cost. The unit cost for labor and actual man-hours may vary significantly, depending on the level of personnel involved and the charge rates of the individuals or organizations actually performing the work. Therefore, these estimates are guidelines only. In addition, program cost and site preparation cost can vary from site to site. These costs will depend on the distances involved and the complexity of providing electrical service to the monitoring location, site security needs and other requirements for site preparation.

The costs presented are reflective of a sophiscated FFMS for a HTRW remediation. The cost presented in Table 3-11 are associated with both administrative/management and hardware/operation of a real-time, FFMS at a HTRW site for a 5-year monitoring program. Table 3-11 outlines cost for program man-hours, equipment cost, and other direct costs.

k. Perimeter air monitoring program mobilization. As identified in Chapter 1, recent remedial actions have required the implementation of a real-time, fixed fenceline volatile organic monitoring system to characterize emissions from hazardous waste sites. The monitoring program normally consists of three basic components:

- Meteorological monitoring system.

- Sample collection system (probe inlet, filter, pump, and heat-trace lines).

- Analytical center real-time gas chromatograph, data management system, and contingency system).

Prior to field deployment, all components of the monitoring program must be evaluated under control conditions to verify their performance and ability to meet design specifications. Experience has shown that time spent "up front" in a program dealing with system evaluation is well spent and saves considerable time in the field. Compare your needs to the manufacturers specifications and determine if the equipment meets the DQO objectives of the project. To assist with the certification of purchased equipment, Table 3-12 identifies component specification checklist to be completed prior to receipt of equipment.

Once the equipment has passed certification at the manufacturer's facility or your facility, it is time to mobilize to the site. It is important to allow sufficient time in the field to receive, assemble and calibrate the various components of the monitoring system. Based upon field experience, a five week mobilization program is not an uncommon length of time. Figure 3-14 illustrates a typical timeline for the mobilization and installation of a real-time, FFMS program.

l. Quality assurance. The purpose of a QA program is to assure that the monitoring results are *of known quality* and that the results are *appropriate for the intended use of the data*. It is important that a clear distinction be made between *quality assurance* and *quality control*. *Quality control* is performed by project management and staff as part of their routine monitoring activities; *quality assurance*, however, must be performed by individuals who are entirely detached from the project and its staff.

Ideally, the QA program should be executed by a "third party" that is not controlled or influenced by the organization conducting the monitoring program. For example, if one contractor has been hired to conduct a monitoring program, a second contractor should be hired to provide a QA evaluation of the work performed by the first contractor. Unfortunately, due to budgetary and/or contractual constraints, it is often not feasible for the second "third party" contractor to be hired.

A more common approach for executing a QA program is for the contractor conducting the FFMS program to also provide its own QA program. While not strictly within the spirit of the QA concept, it is permissible for the monitoring contractor to provide its own QA, provided that the QA personnel (1) are organizationally separated from the project team, and (2) report directly to the higher levels of management. An example of a contractor organizational chart showing the relationship of QA to other organizational functions is illustrated in Figure 3-15.

WBS No.				Description	UOM English/Metric	
331XX	01	06		Temporary Relocations/Roads/Structures/Utilities	EA	EA
	01	07		Construction Plant Erection	EA	EA
	01	08		Institutional Controls	EA	EA
	01	09		Alternate Water Supply	EA	EA
	01	10		Population Relocation	EA	EA
	02			MONITORING, SAMPLING, TESTING, AND ANALYSIS		
	02	01		Meteorological Monitoring	EA	EA
	02	02		Radiation Monitoring	EA	EA
	02	03		Air Monitoring and Sampling	EA	EA
	02	03	01	Real Time	MO	MO
	02	03	02	Non-Real Time	MO	MO
	02	03	03	Asbestos	MO	MO
	02	03	9x	Other (Use Numbers 90-99)		
	02	04		Monitoring Wells	EA	EA
	02	04	06	Gravel Pack Material	CF	M3
	02	05		Sampling Surface Water/Groundwater/Liquid Waste	EA	EA
	02	06		Sampling Soil and Sediment	EA	EA
	02	07		Sampling Asbestos	EA	EA
	02	08		Sampling Radioactive Contaminated Media	EA	EA
	02	09		Laboratory Chemical Analysis	EA	EA
	02	10		Radioactive Waste Analysis	EA	EA
	02	11		Geotechnical Testing	EA	EA
	02	12		Geotechnical Instrumentation	EA	EA
	02	13		On-Site Laboratory Facilities	EA	EA
	02	14		Off-Site Laboratory Facilities	EA	EA

Figure 3-13. HTRW remedial action work breakdown structure (RAWBS)

Table 3-11
Example of Cost Associated With a Real-Time Volatiles FFMS Program For Five (5) Years as Documented by the Corp's HTRW Remedial Action Work Breakdown Structure (RA WBS)

WBS No. 331.XX.02.03.01	YEAR 1	2	3	4	5
1.0 Program Man-hours					
1.1 Organization					
Project Management	200	200	200	200	200
Monthly Reports	96	96	96	96	96
Quality Assurance/Quality Control Project Revised Activities	120	60	60	60	60
1.2 Pre-Mobilization					
Documentation Perimeter Air Sampling Plan (PASP)	100				
-Quality Assurance Project Plan (QAPP)	100				
Purchasing of Equipment	60				
Instrument Calibration in Laboratory	200				
1.3 Mobilization					
Set-up (80 hr/wk x 3 wks x 3 people)	720				
Quality Assurance/Quality Control	40	80	80	80	80
1.4 Monitoring					
Yearly (40 hr/wk x 52 wks x 1 person)	2,080	2,080	2,080	2,080	2,080
1.5 Demobilization					
Break-down (80 hr/wk x 2 wks x 2 people)					320
1.6 Quality Assurance/Quality Control Evaluation	160	160	160	160	160
TOTAL LABOR, MAN-HOURS	3,876	2,676	2,676	2,676	2,996
					14,900

(continued)

Table 3-11. (Continued)

B. Program Equipment	Unit Cost, $	No. Of Units	Total Cost, $
Meteorological Station			
Wind Speed Sensor	450	1	450
NIST Calibration of Sensors	150	1	150
Wind Directional Sensor	450	1	450
Temperature Sensor	350	2	700
Solar Radiation Sensor	450	1	450
Precipitation Gauge	400	1	400
Barometric Pressure Sensor	450	1	450
10 Meteorological Tower	1,000	1	1,000
Data Logger	2,500	1	2,500
Modem	430	1	430
Data Logger Software	400	1	400
Stability Class Software	600	1	600
System Engineering	2,000	1	2,000
Back-up Power Supply	300	1	300
Keyboard Display	400	1	400
Wires, Support to Data Logger	1,000	1	1,000
Recorder, 6 Channel	2,000	1	2,000
Freight	700	1	700
Relative Humidity Gauge	700	1	700
TOTAL			$15,080
Analytical System			
Real-time Gas Chromatograph with "RAM" Option and Speciation Capability	45,000	1	45,000
System Application and Engineering	7,000		7,000
Calibration Gases for 5 years	10,000	1	10,000
Support Gases for 5 years	5,000	1	5,000
System Software for four (4) Level Alarm	2,500	1	2,500
GC Columns for 5 years	4,000	1	4,000
Freight	500	1	500
Supplies for 5 years	2,500	1	$2,500
TOTAL			$76,500
Data Logger			
Data Logger	3,500	1	3,500
Input Channels Engineering	1,500	1	1,500
Input Communication with Other Systems (Meteorological station, real-time GC system and computer)	150	1	150
Relays	280	1	280
Keyboard	680	1	680
Modem	225	1	225
Instrument	125	1	125
Rack	2,970	1	2,970
Personnel Computer	3,900	1	3,900
Software for Calculating "Net" Concentration	4,000	1	4,000
Start-up Application	500	1	500
Freight	500	1	$18,330

Table 3-11 (Continued)

	Unit Cost, $	No. Of Units	Total Cost, $
Perimeter Sampling Stations (5 Year Program)			
Central Analytical Center with Environmental Controls	15,000	1	15,000
Four (4) Perimeter Sampling Stations Set-Up and	3,000	4	12,000
Operational			1,000
Office Equipment (chairs/tables, etc.)	1,000	1	$28,000
TOTAL			
Other (5 Year Program)			
Tools	5,000	1	5,000
Calibration Gases	4,500	1	4,500
Express Mail	1,000	1	1,000
Supplies	3,000	1	3,000
Electricity	3,000	1	3,000
TOTAL			$16,500
Heat-Trace Lines			
Four Stations up to 1,000 ft per Station ($25/ft)	25,000	4	100,000
Temperature Controller	2,000	1	2,000
Installation	5,000	1	5,000
Protective Conduit ($0.50/ft)	500	4	2,000
TOTAL			$109,000

	YEAR				
C. Other Direct Cost	1	2	3	4	5
Project Management					
Telephone	3,000	1,000	1,000	1,000	1,000
Postage & Shipping	800	200	200	200	200
Photocopying	1,500	500	500	500	500
Computer Supplies	300	100	100	100	100
Safety Supplies	500	200	200	200	200
Medical Training	750	750	750	750	750
Other Supplies	250	125	125	125	125
Support	2,000	500	500	500	500
	$9,100	$3,375	$3,375	$3,375	$3,375
Pre-Mobilization					
Telephone	150	---	---	---	---
Postage & Shipping	300	---	---	---	---
Photocopying	500	---	---	---	---
Other Supplies	100	---	---	---	---
Support	400	---	---	---	---
	$1,450				

Table 3-11 (Continued)

	Year				
	1	2	3	4	5
Mobilization					
Airfare	3,000	---	---	---	---
Truck (Leasing: $700/month)	700	---	---	---	---
Room and Board	4,158	---	---	---	---
($66/day x 21 days x 3 people)		---	---	---	---
Telephone	300	---	---	---	---
Car (Leasing: $500/month)	500				
	$8,658				
Quality Assurance/Quality Control Evaluation					
Airfare	5,000	2,000	2,000	2,000	2,000
Car Rental	500	500	500	500	500
Room and Board	1,386	1,386	1,386	1,386	1,386
($66/day x 21 days x 1 person)					
Telephone	200	200	200	200	200
Postage & Shipping	1,000	500	500	500	500
	8,086	4,586	4,586	4,586	4,586
Demobilization					
Room and Board	---	---	---	---	1,848
($66/day x 14 days x 2 people)	---	---	---	---	630
Car ($45/day x 14 days)	---	---	---	---	2,000
Airfare (2 x $1,000)	---	---	---	---	100
Telephone	---	---	---	---	200
Other Supplies	---	---	---	---	300
Freight					5,078

With reference to the real-time, FFMSs, the USACE may require a QA sample (see Paragraph 4-5) using EPA's Compendium Methods as the method in calculating project relative accuracy. The two systems would once again be compared and evaluated against each other. An example of this application might be a collocated sampling canister (Compendium Method TO-14A) at a sampling inlet of a FFMS on-site extractive GC system. The canister would be analyzed for NMOC and speciated organics and compared to the real-time system. Another example may be the requirement for the design, construction, and operation of a mobile trailer containing real-time and time-integrated systems to be used on a prescribed frequency as QA sampler collocated with the on-site FFMS sampling inlets. In operation, the trailer could be rotated between on-site perimeter stations on an established frequency (i.e., 50% of sampling events or one, 24-hour sample per week) to evaluate the accuracy and precision of analytes monitored by the FFMS program. Design considerations for such a trailer must address such consideration as:

- Power requirement (use propane generators to minimize contamination from power source).

Table 3-12
Example of Checklist Associated With Certification of Manufacturer's Guarantees Associated With a FFMS Program

Analytical System (GC)

Q Provide "back purge" capability for sample lines.
Q New "RAM" software verified operational.
Q Modification of bulkhead fitting to allow heating to prevent condensation.
Q Implementation and certification of GC detectors.
Q Software package updated to allow documentation of real-time chromatography.
Q Development of "practical quantitation limits" for the target compounds.
Q Manufacturer cleanliness certification of <2 ppb total volatile organics.
Q Manufacturer development of:
  -Retention time windows for the targeted organics.
  - Documentation of peak geometry for each analyte.
  -Guidelines to evaluate pre-column breakthrough and column deterioration.
Q Incorporation and validation of perma-purge dryer into sample conditioning system for moisture control.
Q Pump capacity to pull sample from up to 1,000 ft away at a flow rate of 39.6 ft/sec at 25" Hg vacuum for an exchange rate of 2.0 units.
Q System capable of sequencing between perimeter points as specified in the Solicitation (sample 5 minutes, dwell 10 minutes).
Q Gas chromatographic system able to report data to analytical center data management system.

Sample Transport System Heat Trace Lines

Q Use of stainless-steel at each junction coupled to Teflon® tubing.
Q Documentation of stability of heat-trace line to maintain temperature at 212 F ± 20 F.
Q Incorporation of direct-readout of temperature in the analytical center for each sample line central trailer.
Q Ability to read temperature in each section by a hand-held thermocouple reader.
Q Provide output for alarm functions from controller data system.
Q Construction of sample inlet system to design specifications.
  - Stainless steel shroud.
  - Heated sintered stainless steel filter (212 F ± 20 F) with efficiency of 99.99%.
  - Filter size of ½" x 2¼" element.
Q Teflon® tube, 0.25" I.D. size for sampling lines, thick wall of 0.375" O.D.'
Q Variable controller in analytical center so heat-trace lines can be adjusted on demand.
Q Lines and J-boxes designed for inclement weather.

Data Management System

Q Ability to accept 0-10V signals from meteorological system and GC system.
Q Ability to initiate four levels of alarm.
  Alarm 1 - 5 minute average NMOC > 1 ppm.
  Alarm 2 - Compound specific perimeter action level.
  Alarm 3 - Compound specific perimeter action level upwind.
  Alarm 4 - Net compound specific (upwind/alarm level).
Q Capability of performing upwind/downwind determination and calculations using real-time meteorological and analytical data.
Q Ability to produce histograms etc. for data review and interpretation.

Meteorological System

Q Ability to provide battery-backed power supplies.
Q Equipped with an RS-232C port for direct communication.
Q Dial-up modem for remote interrogation.
Q Digital-to-analog converters for data logger access.
Q All measurement components (wind speed, direction, stability class, relative humidity, temperature, etc.) NIST certified.

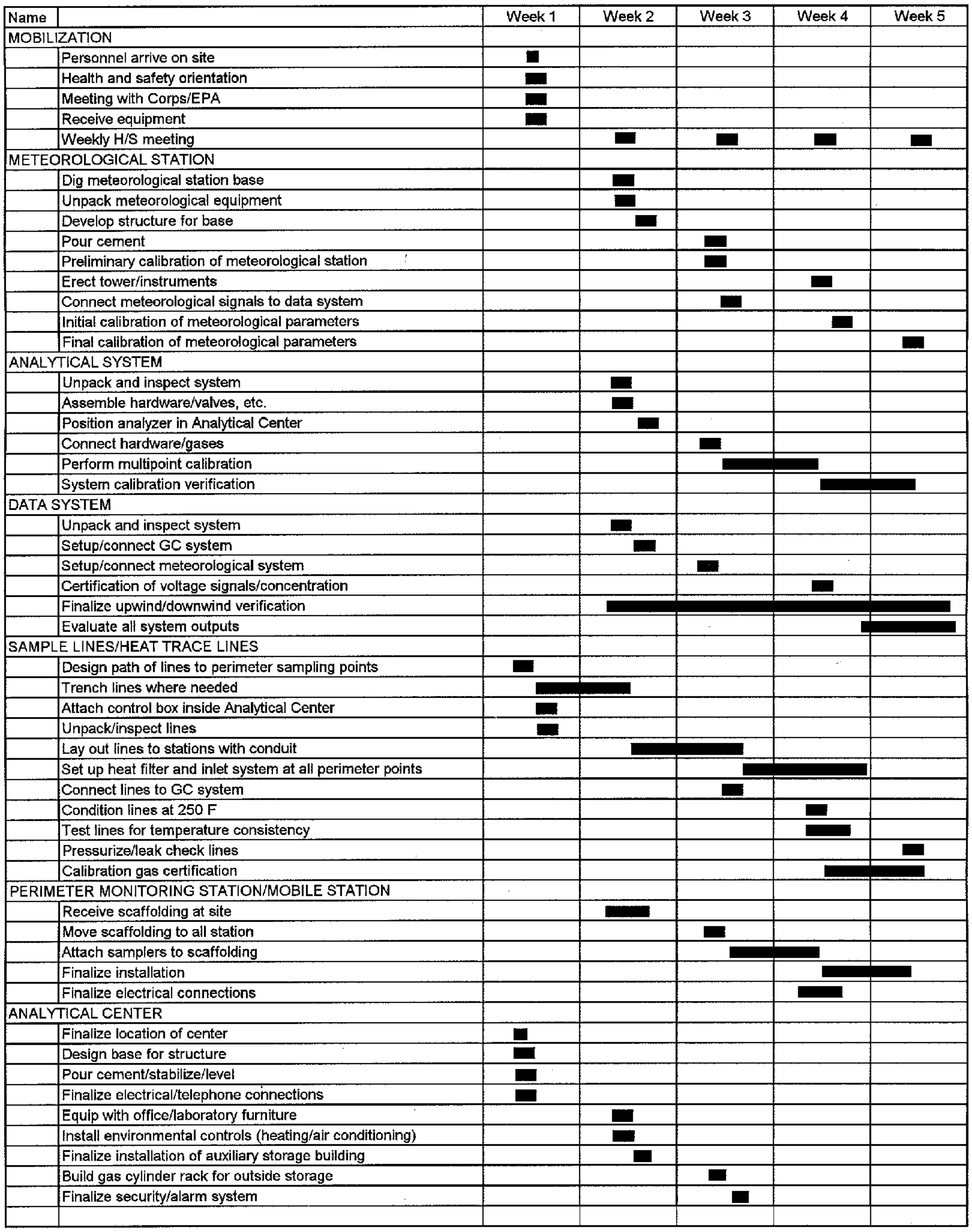


Figure 3-14. Example of a program timeline for establishing a real-time volatile FFMS at a HTRW site

- Mobility (use large oversize tires for better traction during movement on the HTRW site).

- Stability (provide leveling scopes at all four corners of the mobile unit).

- Safety (provide entrance steps and railings completely around the mobile unit).

Finally, a quality assurance plan (QAP) should be prepared as a separate document to the HTRW sampling and
analysis plan. It is important that the QA plan be prepared well before the start of the monitoring program so that there will be sufficient time for the Plan to be reviewed and approved by all interested parties. The important elements of a QAP are listed below and discussed extensively in Chapter 8.

- Project description, including intended use of the data.

- Project organization and QA/QC and responsibilities.

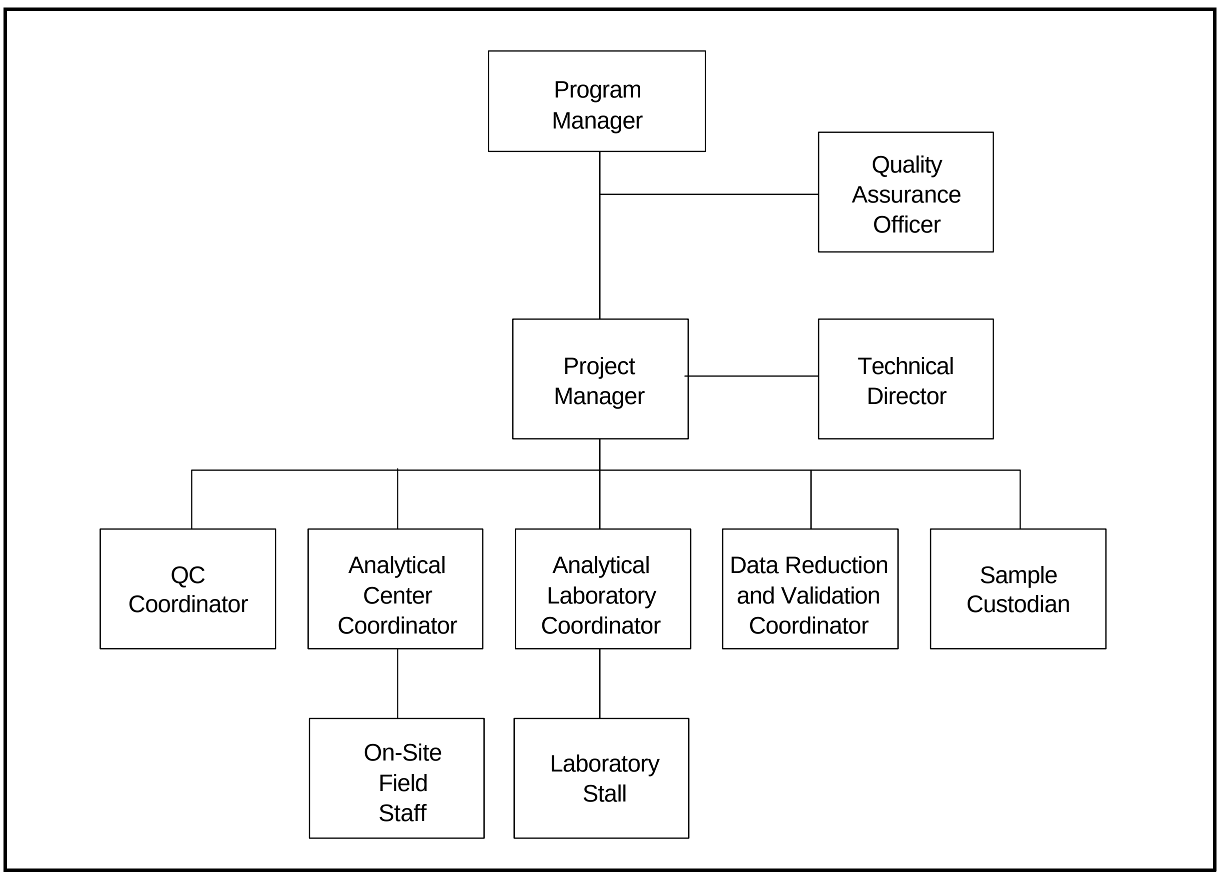


Figure 3-15. Example of contractor organization chart showing relationship of quality assurance to other organizational functions for a real-time volatile FFMS

- Data quality objectives for critical measurements, in terms of precision, accuracy or bias, completeness, representativeness, and comparability, or qualitative acceptance criteria when quantification is not practical.

- Site selection and sampling procedures.

- Sample custody.

- Calibration procedures and frequency.

- Analytical procedures.

- Data reduction, validation, and reporting, including handling of invalid/missing data.

- Internal QC checks and audits.

- Results of performance and systems audits.

- Preventative maintenance (procedures and schedules).

- Calculation of data quality indicators; specific procedures and statistical methodology to be used in routinely assessing and evaluating data precision and accuracy or bias (both QC and measured), representativeness, comparability, and completeness of the specific measurement parameters involved.

- Corrective action (criteria and procedure).

- QC reports to management.